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PAPERS AND DISCUSSIONS

THE PURIFICATION OF THE WATER SUPPLY OF STEELTON, PENNSYLVANIA.

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The plant for the purification of the Steelton water departs, in several particulars, from previously constructed types, and embraces features of some novelty. The interest expressed by engineers and municipal authorities who have visited it, and seen it in operation, inclines the writer to believe that, although the plant is not a large one, a description of the conditions leading to its design, as well as an account of its construction and the results thus far obtained in its operation, would bring out an instructive and useful discussion of certain subjects on which more information is desirable.

The plant is a slow sand filter having a capacity of 3 000 000 gal. of filtered water daily; and among its novel features are:

1. The use of coarse-grained filters instead of subsiding basins in the preparatory treatment of the water;
2. The small area required—about one-fourth of that ordinarily required for a slow sand filter plant of equal capacity;
3. The system of handling and caring for the sand removed from the slow filters during scraping;

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4. The system of determining, measuring, and applying the chemical solutions;
5. The construction of, and the filtering materials in, the roughing filters;
6. The method of operating the roughing filters, and the safeguards to prevent the deterioration of the effluent;
7. The control of the rate of filtration of the slow filters.

Among the novel features pertaining to the operation of the plant are the following:

1. The very high rate of operation of the slow filters;
2. The small quantity of coagulant necessary to secure satisfactory results—about one-fifth of that required in a mechanical filter plant of equal efficiency, and about one-eighth of that required to secure equally satisfactory results with coagulation and subsidence;
3. The ease of manipulation of the chemical dosing, and the certainty in its application;
4. The long runs of the roughing filters when no coagulant is necessary, and the consequent saving in wash-water, power, and attention;
5. The long runs of the slow filters, and the resulting large quantities of water filtered between scrapings;
6. The uniformity in the quality of the water applied to the slow filters, and consequently the satisfactory results obtained in the final purification;
7. The brilliancy of the effluent from the slow filters;
8. The absence of trouble with rusty hot water and troubles from the destruction of the solder in copper closet tanks;
9. The moderate cost of construction and operation.

The Borough of Steelton, having a population of approximately 15 000, is in Dauphin County, Pa., on the same side of the Susquehanna River as Harrisburg, and about 3 miles farther down. Topographically, the territory within the borough limits consists of a flat portion, about 20 ft. above the level of the river and from 1 000 to 1 500 ft. in width, which extends the whole length of the borough, and the residential district, which extends up the side hill to the east, and is much broken, and traversed by streets having for the

most part heavy grades. The principal street skirts the eastern edge of the flat area, the larger portion of which is occupied by the works of the Pennsylvania Steel Company.

Original Water-Works.—The original water-works plant was built by the Steelton Home Water Company, and was purchased by the borough in the latter part of 1899 for $150 069.48, since which time improvements to the intake, pumping station, and reservoir, and extensions of the street mains swelled the total cost to $223 000, on January 1st, 1906, of which $145 000 was the cost of the street mains, $38 000 the cost of the reservoir, and about $40 000 the cost of the intake and pumping station. The plant, at that time, obtained its water from the Susquehanna River through a 16-in. intake pipe reaching out approximately 1 400 ft. from the pumping station, to within about 150 ft. of the shore of Stuckers' Island. The original supply had been derived from wells dug on that island, but in a comparatively short time it became impossible to keep up the supply from the wells, and a pipe was extended about 50 ft. out into the river from the most southerly well, the water being then drawn from the river to the wells and back to the pumping station through the 16-in. pipe. Subsequently, owing to the silting up of the wells and their inaccessibility during high water in the river, a section of the 16-in pipe was taken out at a point about 150 ft. east of the island, allowing the water to enter the pipe from the river direct; it was in this condition on January 1st, 1907.

The water flowed through this broken-into intake pipe to a brick-and-concrete-lined well situated about 150 ft. from the river, just east of the Pennsylvania Railroad tracks, and was pumped from this well to the service reservoir, 270 ft. above the river, by two 1 500 000-gal. Deane, compound, direct-acting, outside-packed, plunger pumps, through a 12-in. force main. An additional 16-in. main, connected up at the pumping station to permit either pump to pump direct or to the reservoir, parallels the 12-in. force main for about 1 200 ft., extending to Second Street on Connestoga, and is cross-connected with the distribution system and the 12-in. force main. The service reservoir, when full, holds about 7 500 000 gal.

Character of Susquehanna River Water.—The Susquehanna River, above Steelton, has a water-shed of approximately 24 300 sq. miles. It drains practically one-half of the State of Pennsylvania, and about

6 080 sq. miles in the southern central portion of New York State. Upon its banks are many large cities, including Binghamton, Cooperstown, Corning, Elmira, Hornellsville, Horseheads, and Owego, in New York State, and Athens, Altoona, Bellefonte, Clearfield, Emporium, Harrisburg, Hazleton, Huntingdon, Lewistown, Lock Haven, Mahoning, Mifflintown, Mount Carmel, Nanticoke, Pittston, Plymouth, Sayre, Scranton, Shamokin, Sunbury, Towanda, Tunkhannock, Tyrone, Wilkes-Barre, and Williamsport, in Pennsylvania. Approximately, 1 000 000 persons reside in the cities and towns along the river and its branches above Steelton, of which probably 750 000 are located along the North Branch, about 100 000 on the West Branch, and 150 000 on the Juniata, which streams unite a few miles above Steelton to form the main Susquehanna River. In addition to this urban population, there is a very large rural population, and, of the larger cities, there are upwards of 60, having a total population of about 700 000, which have sewers discharging directly into the river and its branches.

The anthracite coal fields of Pennsylvania are on the water-shed of the North Branch, and along the whole length of the river and its tributaries there are many important manufacturing industries, the wastes from which are discharged into its waters. The West Branch lies largely in a sandstone country, and the principal industries along it have been in connection with the manufacture of lumber. The Juniata lies very largely in a limestone district.

In the days of canal navigation, several dams were built on each of the main streams, canals paralleling the streams on one side, or both, between the pools formed by the dams. The principal dams on the North Branch were at Clark's Ferry, Sunbury, Nanticoke, Wilkes-Barre, and Binghamton; on the West Branch, at Lewisburg, Muncy, Williamsport, Lock Haven, and Queen's Run; on the Juniata, at Millerstown, Lewistown, Newton, Hamilton, and Huntingdon; and on the branches at Pipers, Petersburg, Big Water Street, Little Water Street, Willow Street, Donnellys, Smokers, Mud, Williamsburg, Three Mile, Crooked, Frankstown, and Hollidaysburg. The existence of these dams is mentioned because they play an important part in the modification of the character of the river water during the season of low water as well as during the early stages of the fall and spring floods. Essentially, it will be seen that these various streams consist of a series

of comparatively steep natural slopes joining level pools, which, during low and moderate stages of water, form subsiding basins in which suspended matters carried by the water may be deposited in greater or lesser amounts. During freshets, however, the deposits which may have accumulated in the pools during the preceding quiet periods are scoured loose from the bottom, picked up by the rushing waters in a more or less changed condition, and carried down the stream in large quantities.

The larger part of the water-shed is semi-mountainous, the main streams flowing, for the greater part, through unerodable, and comparatively steep valleys, and the hillsides being largely denuded of forest areas; for this reason the stream and its branches are more or less flashy, big floods rising to a height of many feet in a few hours and falling almost as rapidly.

The amount and character of the sediment in a turbid water is of importance in determining the method of preliminary treatment best adapted to prepare the water for final purification. At Steelton, the quantity which will subside to the bottom of a 1-gal. bottle will sometimes reach a depth of ½ in., and is usually a composite of sand, coal dust, leaves, stones, silt, nitrogenous matter, coagulated clays, as well as aluminum hydrate and the hydrated oxides of iron mixed with various forms of dirt, bacteria, and other matters.

In the Susquehanna River water at Steelton a brown sediment, varying from red to yellow in color, either flocculent or otherwise (the flocculence depending largely on the stage of the river and the influence of the stage on the accumulation of bacterial masses and clay particles into agglomerations), is generally characteristic of the water in the west channel, although a sediment of this color may sometimes occur over the whole width of the river, following heavy general rains. A microscopic examination of this brownish sediment shows that it consists of particles of coal and dirt agglomerated by growths of small water plants and filamentous bacteria, probably of the order *Bacterium*, or *Leptothrix*.

A greenish-black sediment, resulting from the mixture of coal dust and clay, is generally flocculent, and is characteristic of the water in the east channel during heavy floods.

A grayish sediment, due either to finely-divided suspended matter other than clay, or to the hydrates of aluminum and of iron, which

settle to the bottom when the river is low, is characteristic of the water in the east channel, and is locally called "sulphur water."

A black sediment, generally more or less flocculent, consisting of finely-divided particles of coal from the mining districts, is characteristic of the east channel, and can be observed on the bottom of the river below islands and bridge piers, and in other protected positions when the river is at low stages.

All possible gradations of color intermediate between these are observable at different times owing to the commingling of the different waters.

The presence of red or yellow clay in the Susquehanna River water at Steelton, in increasing quantities, is almost uniformly accompanied by decreasing alkalinity; such water clears up slowly by subsidence. The water carrying flocculent sediment, which is generally black during floods but often the clean hydrate when the river is low, will clarify very quickly by subsidence. Such waters are characterized by low alkalinity and correspondingly high permanent hardness.

The color of the turbidity of the Susquehanna River water, therefore, is a fairly good index of its character, and, during the operation of the filters, plays an important rôle as a guide to the proper use of the coagulant.

The changes which take place in the character of the sediment, as the result of bacterial activity, are intimately associated with the iron, sulphur, and alkaline constituents of the water. Shortly after the Harrisburg experimental filtration plant was put in operation, in the fall of 1902, one of the roughing filters, then operating without a coagulant, became suddenly clogged to a condition of water-tightness within a very few minutes after the turbid raw water was turned on, and an examination disclosed a heavy blanket of black, sticky mud on the surface of the sand. It was surmised that this mud might be similar to that which was reported to have accumulated in the sedimentation basins at Cincinnati during the experiments conducted by George W. Fuller, M. Am. Soc. C. E., but a chemical examination of the mud on the Harrisburg filter showed that while iron was present in considerable quantities it was not in the sulphide form. The mud was found to consist essentially of very fine particles of coal dust mixed with the hydrates of iron and aluminum.

Although it had been understood for a long time that the drainage

from coal mines contained a considerable quantity of free sulphuric acid, an explanation of the processes by which this was formed was not generally current. Recognizing that ferrous sulphide, as pyrites, was present in the coal dust in the river, it was suspected that the "sulphur bacteria" and "iron bacteria," which work various transformations in iron compounds, might play some part in the formation of this sulphuric acid, and an experiment was made to test the hypothesis. A small quantity of coal dust or culm was pulverized in a mortar, and equal portions were placed in narrow-mouthed bottles. In each of these bottles was then placed a definite quantity of untreated river water, and, the mouths of the bottles having been closed with cotton plugs, half the number were sterilized in an autoclave at a pressure of 15 lb. for 30 min. After standing in the laboratory for about a month the bottles which had not been sterilized exhibited very different characteristics from those which had been so treated. After both sets of bottles had been shaken violently the turbidity in the set which had not been sterilized was observed to decrease very much more rapidly than that in the set which had been sterilized, somewhat after the manner that the untreated river water containing this hydrated oxide of iron acts in comparison with water which does not contain it. The water in these bottles represented, in some degree, the condition of the water in the river, except that the bottles which had been sterilized contained no living bacteria, while the others, supposedly, did, having been filled with river water which at the time of filling was known to contain a large number. The results of this preliminary experiment seemed to indicate that the change which had taken place in the unsterlized bottles was due to the action of the bacteria on the iron compounds contained in the culm.

Following out this idea, a further elaborate set of tests finally led to the conviction that a hydrate of iron was formed from the pyrites, in the presence of bacteria, while it was not formed when bacteria were absent; further, there was no evidence of the formation of soluble iron except when bacteria were present.

The reactions which took place in the bottles used in the experiments are not known, and are probably of a very complicated character, some resulting directly from, or being intimately associated with, the biological activities present, and others in all probability being spontaneous chemical reactions. It would be foreign to the subject of

this paper to enter into a discussion of these experiments in detail and of others which have since been made both on Susquehanna and on Schuylkill waters; it will be sufficient to state that at the conclusion of the Harrisburg experiments the data indicated that the bacteria occurring normally in the Susquehanna River, in the presence of organic matter on which they can live, and under proper conditions of storage, are able to transform the pyrites in the coal into compounds which furnish the material for the hydrated oxide of iron naturally occurring in the water. The indications seem to be that the sulphur in the pyrites, in contact with water, furnishes the material from which the bacteria make sulphuric acid, which, coming in contact with the iron, forms the soluble ferrous sulphate. The water containing this soluble ferrous sulphate commingles with the alkaline waters of the river farther down stream, the sulphate of iron being decomposed, the sulphur combining with the lime and magnesia to form the sulphates of these bases, and the iron being converted into the hydrate and subsequently into the hydrated oxide. This seems to be at least one method by which free sulphuric acid is formed in the drainage of the mining regions; the process also takes place to a very considerable extent in the level reaches of the river, where culm is deposited as floods recede. When the river rises, and the dirt on these flats is washed away, there is borne with it the hydrate and hydrated oxide of iron which had been formed during exposure. At the Clark's Ferry dam, some miles above Harrisburg, the water in the east channel sometimes shows this coagulated condition so plainly that frequently within an area of a few square feet one may collect a sample of either perfectly clear, or very black water.

At times of very low water there occurs along the east shore a brownish flocculent sediment composed of the hydrate of aluminum as well as the hydrate of iron. The source of the aluminum entering into the composition of this hydrate is unknown; possibly it is derived in some way from the clays.

As a result of the natural formation of the hydrated oxide of iron, and of aluminum hydrate, in the water of the river, a considerable degree of apparent self-purification takes place during the summer months. This is brought about, in the pools above the dams, by the entangling of the bacteria into flocculent masses and their consequent settlement to the bottom of the river with the other suspended

matter. The action is, on a large scale, very similar to the results of the treatment of sewage by chemical precipitation, and the active precipitants are the same as those used in the artificial process. Ultimately, a large proportion of the organisms thus carried to the bottom cease to exist in an active condition, finding their environment not suited to sustain their vitality. The apparent purification is at times so great that, although from the many cities along its course enough sewage is flowing continuously into the river to render the water at its extreme low stage offensive, yet at such times the water, as it flows past Steelton, is actually at its best, both in appearance and as to its hygienic qualities. The analyses of different samples of river water collected at Harrisburg during low water have shown as few as 10 colonies of bacteria per cu. cm., with no intestinal bacteria present; and generally, during low-water stages, when the quantity of sewage discharged into the river is greatest relatively to the stream flow, the numbers of bacteria in the river water opposite Steelton (from points far enough away to be beyond the influence of the Harrisburg sewage) are lowest and the numbers of intestinal bacteria fewest. This condition obtains, however, only during dry weather, for the first floods which come down in the fall scour out a portion of the deposits from the pools formed by the dams up stream, and then the counts show sometimes as many as 300 000 colonies of bacteria per cu. cm. of water, as well as large numbers of bacteria characteristic of intestinal discharges.

The total hardness of the river water varies with the stage of the river, yet not necessarily in proportion thereto, and is about the same, as a general thing, from bank to bank. The water is hardest at low stages when the flow is largely from springs, that on the west side being high in carbonates and low in sulphates while that on the east side is low in carbonates and high in sulphates, owing to the chemical changes taking place, as above described.

These modifying conditions destroy any relationship between turbidities, river stages, and numbers of bacteria. High bacterial counts sometimes accompany very low, as well as very high, turbidities, and, similarly, relatively low turbidities are sometimes found at very high stages of the river; further, the color of the turbidity is no indication of its total amount, as a comparison of the records of ten samples of water, each with a turbidity of 1 000 parts per million, collected at

different times, and at different parts of the river, shows all gradations of colors between bright yellow, red, dark brown, and black.

As a result of these complex conditions, the water in the river may change quickly from a moderately hard, clear water to a soft water carrying several thousand parts per million of turbidity, which, on occasions, may intermittently come down coagulated to a more or less slimy or flocculent condition with hydrated oxide of iron and hydrate of alumina. On the other hand, the river from bank to bank may be carrying its maximum load of yellow clay from the Conodoguinet and Juniata, or reddish-brown mud from the West Branch. During a general flood from the entire water-shed, all these conditions may prevail at the same time, the yellow water from the Juniata keeping on the western side, the West Branch water keeping in the central part, and the black water from the North Branch along the eastern shore, each stream occupying practically one-third the width of the river, which, opposite Steelton, is approximately four-fifths of a mile.

Although of great width, the river is comparatively shallow, the bed in that vicinity being of shale and limestone, and the depth of the water at its lowest stage being not more than 3 ft. at any point and not more than 1½ ft. for the greater part of the width. Some trouble is caused during the winter by slush-ice and anchor-ice, the formation of which is favored by these conditions.

The Steelton Filter Plant.

Those who have had experience in the filtration of polluted waters will appreciate some of the difficulties encountered in the purification of the Susquehanna River water, particularly as to bacterial purification, for the reason that the numbers of bacteria in the raw water may be increasing rapidly while the turbidity is decreasing; and hence, if the attempt is made to control the bacterial purification by operating the plant on the indications of the removal of turbidity only, the result may be anything but satisfactory.

Another complication arises from the exhaustion of the alkalinity of the raw water by the acid mine wastes, and also its reduction by dilution during heavy freshets. This, however, can readily be taken care of by adding enough lime or soda-ash to supply the deficiency in alkalinity, in case a coagulant is used in connection with the process

of purification. Among other complications is the difficulty of securing the satisfactory coagulation of the raw water when the bacterial counts are high and the turbidity is low, and also the difficulties encountered in securing a sufficiently heavy coagulum when the temperature of the water approaches the freezing point, at which times the turbidities are also usually low.

While all these difficulties can be overcome and the water can be handled successfully with a mechanical filter plant such as that installed for the City of Harrisburg, the successful operation of such a plant depends on the maintenance of a fully equipped laboratory, and on a superior grade of supervision; and, to secure these, it is essential, of course, that the revenues derived from the sale of the filtered water be sufficient to cover the additional expense.

Owing to the considerable general pollution of the river, the discharge of the sewage of Harrisburg into it only a couple of miles above Steelton, the excessive turbidity, and the enormous quantities of sand and coal delivered into the borough's distributing reservoir by the supply pumps (ultimately to enter the distribution mains, interfering with the action of meters, and clogging service pipes), the question of securing a purer and more satisfactory source of supply was brought to an issue in the winter of 1906, and the writer was commissioned to investigate and report on what could be done toward securing a new supply of a satisfactory quality, or toward purifying the existing supply. The report recommending the purification of the present supply was submitted to Councils early in 1907, and, following its adoption, the borough voted to issue $80 000 in bonds to cover the cost of the necessary works.

The plant, as built, was designed to place the securing of satisfactory results, as to purification, within the reach of the Water Department without the necessity of maintaining a laboratory, and without incurring unduly heavy construction and operation costs. The general basis of the design is as follows:

First.—The removal by subsidence of such of the suspended matters as will settle out from the raw water in about 12 min.;

Second.—The removal, by passing the water rapidly through deep, coarse-grained filters, of at least 90% of the applied turbidity, using a coagulant to secure this result when necessary, and allowing no coagulated turbidity greater than 25 parts per million to issue from

the coarse-grained filters, no matter what the turbidity of the applied water;

Third.—The filtration of the effluent of the coarse-grained filters through slow sand filters at a relatively high rate.

New Intake.

The works include a new 30-in. cast-iron intake pipe extending out about 1 500 ft. into the river to a point where observations indicated that there would be a minimum of trouble with silt, sand, and coal dust. At the point where the intake was located prior to the commencement of these improvements large quantities of sand and fine particles of coal were drawn into the intake well during floods in the river, as much as a car load a week requiring removal in order to keep the pumps in operation.

The new intake pipe was laid to proper line and grade, in cofferdams, in a trench excavated in the rock bottom of the river, the joints being poured with lead and caulked water-tight.

The intake cage consists of a reinforced concrete structure inclosing the end of the intake pipe and spreading out like a fan to give an opening in front 1 ft. high and 20 ft. long, with vertical screen bars of 1-in. round steel, spaced 6 in. apart, in two rows, and staggered. The top of the opening was located at a depth of 1 ft. below extreme low water, and the rock bottom of the river was blasted away in front of the cage, a smooth concrete apron being laid thereon to assist the current in rolling sand and coal particles along past the intake. The line of the face of the intake is parallel with the trend of the current of the river at that point.

A valve is placed in the intake pipe, at the shore end, and a connection is made with the existing 24-in. pipe leading to the suction well. The work on the intake, which was commenced on July 1st and completed early in September, 1908, was done by the Water Board by day labor, from the plans and under the general supervision of the writer.

Improvements at the Pumping Station.

New Pumps.—The plans, as approved by Councils on July 10th, 1907, called for the construction of a 3 000 000-gal. slow sand filter plant with roughing filters, to be built on a piece of ground 100 ft. wide and 265 ft. long, situated about 700 ft. east and 900 ft. north of

the pumping station. Before the construction of the works had been authorized, appropriations had been made for the installation of a new 3 000 000-gal., Heissler, compound-condensing, crank-and-fly-wheel, pumping engine at the pumping station.

In order to suit the new conditions, it was necessary to remodel the piping in the pumping station and install two 12-in. centrifugal pumps, direct-connected to simple, vertical, condensing engines of the marine type, the suction pipes of the new pumps being connected to the remodeled original suction to which the suctions of the old Deane pumps were attached. The discharge pipe from the two centrifugal pumps was piped to the filter plant, with provision for a cross-connection to the suction pipe of the new Heissler pump, so that, in case of accident to the new filtered-water well, raw water could be pumped directly into the Heissler pump and thence to the city. The Deane pumps were located in a pit sufficiently low to enable them originally to take their own suction from the intake well, but the new Heissler pump, as well as the remodeled Deane pumps now take the filtered water from a new filtered-water well constructed just outside of the pumping station.

From this brief description it will be seen that in the remodeled plant the raw water is pumped from the intake well by centrifugal pumps to the filter plant, and the filtered water is returned to the new pump well just outside of the pumping station, from which either the new Heissler or the old Deane pumps can draw the filtered water and force it through a 12-in. force main to the distribution reservoir on the hill above the town, or through the 16-in. return main directly into the distribution system, or into the reservoir and the distribution system at the same time by properly manipulating the control valves on the cross-connections. By this arrangement the construction of an additional force main to the reservoir, which would have been an immediate necessity owing to the increased consumption of water, was deferred for many years by reason of the provision of a pure water which could be pumped into the mains direct.

Raw-Water Delivery and Filtered-Water Return Mains.—The raw-water pipe leading from the pumping station to the filter plant, and the return pipe leading from the filter plant to the new pump-well are of wood-stave construction, with cast-iron specials for bends and connections to the concrete.

preparing the raw water for slow filtration by removing therefrom enough of the turbidity and bacteria to permit the slow filters to be operated at a relatively high rate. The object of the treatment is to prepare the water in such a way as to be able to discharge upon the slow filters, for final purification, a water of reasonably constant composition, as to turbidity and bacterial contents, throughout the entire year, keeping the maximum limits of turbidity and numbers of bacteria in the applied water down below figures which experience indicates to be desirable.

The treatment begins with the removal of the floating matters from the water by coarse screening and of the particles of sand, silt, and coal dust by subsidence. The water is then passed through roughing filters containing a deep bed of coarse-grained filtering material in which an additional portion of the remaining suspended matter (including a varying percentage of bacteria) is retained, the effluent water passing to the slow sand filters for final purification. As a general rule, when the numbers of bacteria in the raw water are relatively low and when the turbidity does not exceed 50 parts per million, the roughing filters produce an effluent of satisfactory quality without the use of artificial coagulation; but when the turbidity of the raw water is higher than 50 parts per million, or when it is caused by particularly fine particles, or when the bacteria number more than about 5 000 per cu. cm. in the raw water, a sufficient quantity of coagulant is mixed with the incoming raw water, as it enters the deposit chamber, to produce a rough filtered effluent with a turbidity of not more than 10% of that of the applied water, and not more than 25 parts per million, in any case. Adherence to these limits, which are as yet only tentative, will apparently give sufficiently long runs of the roughing filters to permit of easily keeping the plant in operation, and sufficiently long periods of operation of the slow filters to enable them to pass a satisfactory quantity of filtered water between scrapings.

The period of subsidence allowed in the deposit chamber, for the maximum capacity for which the plant is designed, is 12 min. The roughing filters are designed to operate at a rate of 172 000 000 gal. per acre of filter surface per day when delivering 1 500 000 gal. per filter, three filters being provided so that two can yield the full 3 000 000 gal. while the third is being washed. The net area of the sand surface of each slow filter is 0.1446 acre, and when delivering 1 500 000 gal.

per day the filter will operate at a rate of 10 373 000 gal. per acre per day, two filters yielding 3 000 000 gal. daily with the third in reserve for cleaning.

Deposit Chamber.—The raw water is received at the filter plant at the bottom of a rectangular compartment in one end of the reinforced concrete deposit chamber, Plate XLVII, a valve-controlled connection being provided between the bottom of this compartment and the sewer. One outlet from the upper part of this compartment leads to the deposit chamber and a second leads directly to the channel feeding the water to the roughing filters. By using one or the other of these outlets the water may be passed through the deposit chamber, or, if desired, the deposit chamber may be by-passed and the raw water delivered directly to the roughing filters. After leaving the inlet chamber, on its way to the deposit chamber, the water first passes vertically downward through a coarse screen composed of parallel lines of 2-in. planks standing on edge, horizontally, and spaced about 8 in. apart from center to center transversely to the direction of the entering water; between these planks, and in a vertical plane, one above the other, are the horizontal perforated pipes through which the lime-water and coagulant solutions are admitted to the raw water.

The raw water is admitted to the deposit chamber in the manner described, in order to use up the entering velocity head and permit the water to pass through the deposit chamber quietly and thus drop out as much as possible of the suspended matter in the short time allowed therefor.

Grit Elevator.—Near the end at which the raw water enters, a grit elevator is installed to remove continuously the sand and coal particles which may collect in the deposit chamber. The elevator, Plates XLVII and XLVIII, which has an estimated capacity of 20 tons per 24 hours, consists of an 8-in., 6-ply rubber belt carrying perforated, galvanized-iron buckets, 6 in. long, 4 in. wide and 4 in. deep, at intervals of 2 ft. The belt travels at the rate of 25 ft. per min., and the buckets discharge into a hopper arranged to fit into the end of a 6-in. cast-iron pipe leading to one of the sewer compartments of a roughing filter.

The deposit chamber is 10 ft. wide and 42 ft. long, including the entrance chamber and screen box, and at full capacity the water flows through it with a depth of about 9.2 ft. and a velocity of 0.05 ft.

per sec., passing over a weir at the farther end into a channel leading to the inlet openings to the roughing filters.

Chemical-Mixing Tanks.—Vertically above the deposit chamber, and carried on heavy reinforced concrete beams spanning the chamber, stand the mixing tanks, Plates XLIX and L, for the lime-water and coagulant solutions. These tanks are of monolithic reinforced concrete. In each tank there is a wooden dissolving rack with an open bottom carrying wooden frames provided with copper screens having 20 meshes per inch, reinforced by a coarse copper screen having 4 meshes per inch, with No. 11 bars. Each tank is provided with a system of ⅝-in. perforated copper pipes at the bottom connecting with a line of galvanized-iron pipe leading from above the tops of the tanks to the air receiver, to provide for the agitation of the solution after it has been mixed. A galvanized-iron steam connection, with a copper branch reaching to the bottom of the coagulant tanks, is provided for warming the solution during cold weather. The solution is mixed in the usual manner. With a 2% solution, two tanksful will furnish a dose of 2 gr. per gal. for a consumption of 3 000 000 gal. daily. The coagulant solution is drawn from the mixing tanks through 2-in. copper pipes arranged with swivel-joints to permit of decanting the solution at any desired depth.

Coagulant-Measuring Box.—Through the copper outlet pipes the solution runs to the coagulant-measuring box, Fig. 1, and Fig. 1, Plate LI. This is a reinforced concrete box with a plate-glass front in which are drilled three ¼-in. and three ½-in. orifices, all at the same elevation and spaced 4 diameters apart and 4 diameters of the ½-in. holes from the bottom and side edges of the plate. This glass plate is 11 in. wide, ¼ in. thick, and 28 in. high, and the holes are countersunk one-half the depth of the plate from the outside. On the back of the plate is etched a graduated scale reading to hundredths of a foot for a height of 2 ft. above the centers of the orifices. The plate is fastened to the front of the orifice box on soft rubber gaskets, made of tubing, by brass plates and expansion bolts secured in the concrete. The depth of the solution in the orifice box is regulated with a bronze lever valve and float arranged to admit the solution near the bottom and permit the regulation of the depth in the box by changing the height of the float. The float is of copper, 10 in. in diameter, with a flat bottom and a coned top, sliding on a ¼-in. brass rod, the rod being

hinged to the lever of the valve, and the height of the float being adjusted on the rod with a bronze set-screw having a milled head.

Each orifice is provided with a soft rubber cork, or stopper, attached to a handle consisting of a piece of brass pipe with a cap on one end and an elbow on the other, the cork being fastened to a nipple entering the elbow; there is a rack, with thumb-screws, across the top of the orifice box, for holding the handles where desired.

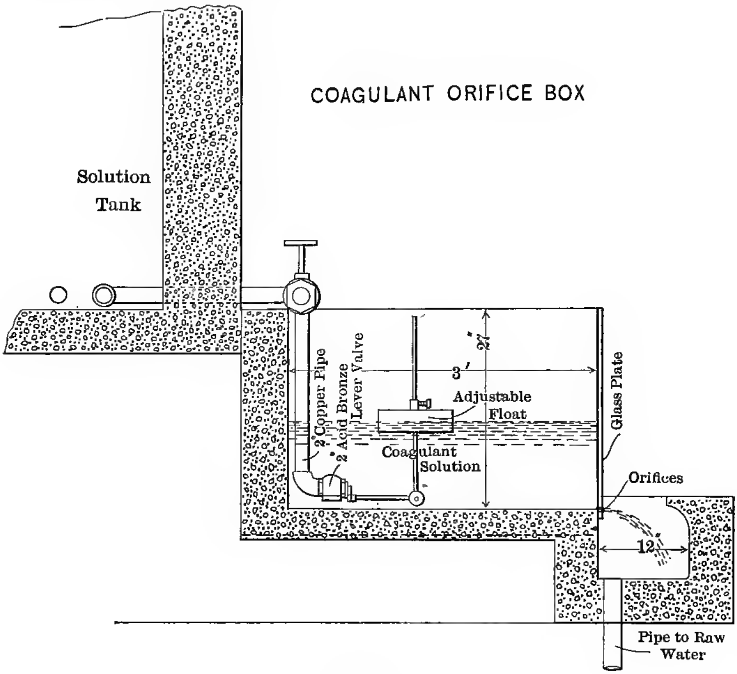
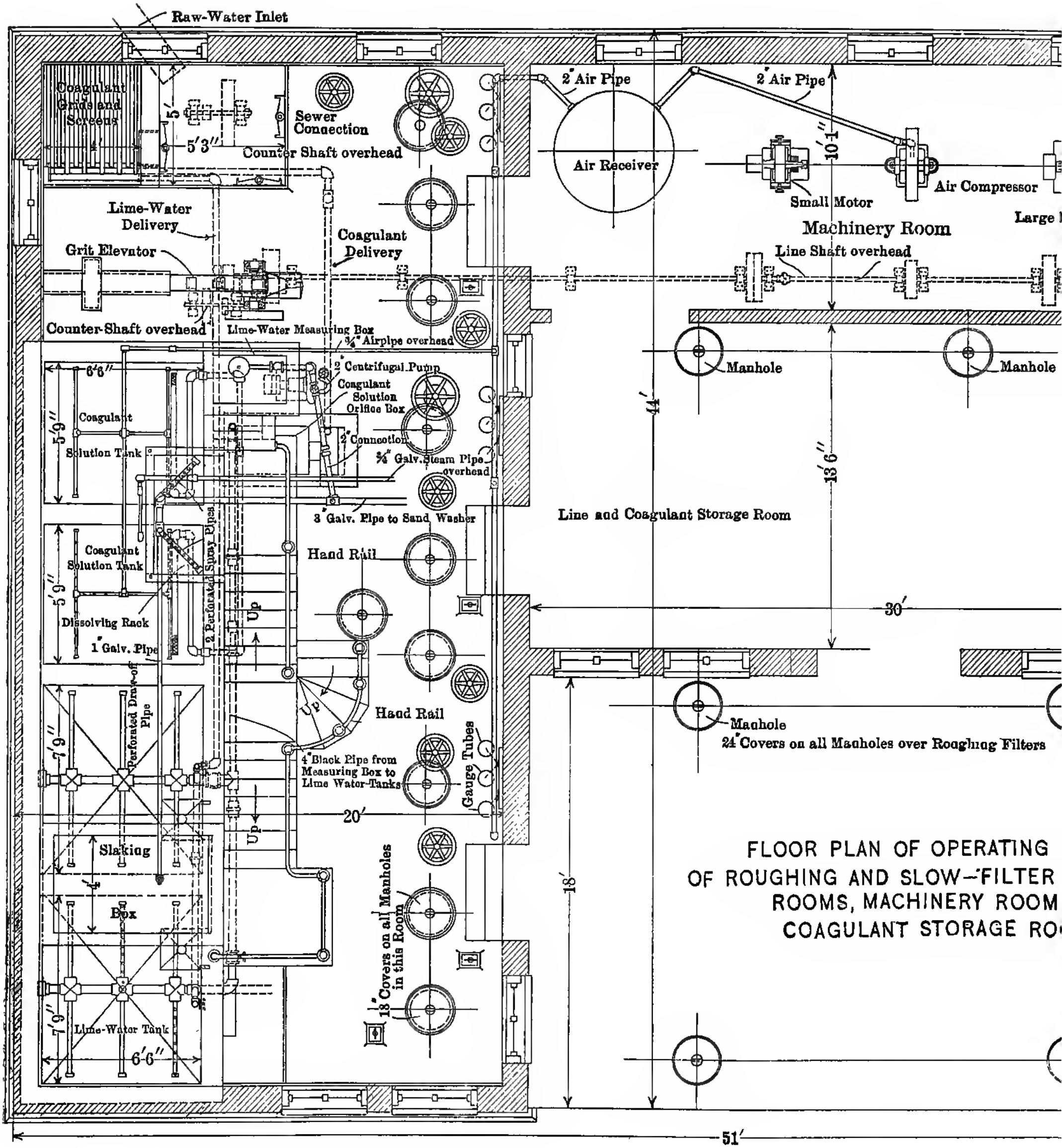


FIG. 1.

The coagulant solution flows through the orifices in the glass plate to a small concrete box, from which a 2-in. copper pipe connects with the perforated pipes between the screen bars at the entrance to the deposit chamber.

Lime-Water Mixing Tanks.—The lime-water apparatus consists of two tanks for making the lime-water (Plates XLIX and L), a slacking box, and an orifice box for measuring the quantity of water to be supplied to the lime-water tanks. Lime being only slightly soluble in water, a relatively large quantity of solution is required



Raw-Water Inlet
Coagulant Grids and Screens
5′
5′3″
Sewer Connection
Counter Shaft overhead
2″ Air Pipe
2″ Air Pipe
Air Receiver
10′1″
Small Motor
Air Compressor
Large
Machinery Room
Line Shaft overhead
Lime-Water Delivery
Grit Elevator
Coagulant Delivery
Counter-Shaft overhead
Lime-Water Measuring Box
¾″ Airpipe overhead
2″ Centrifugal Pump
Coagulant Solution Orifice Box
2″ Connection
¾″ Galv. Steam Pipe overhead
3″ Galv. Pipe to Sand Washer
Manhole
Manhole
44′
13′6″
Line and Coagulant Storage Room
6′6″
5′9″
Coagulant Solution Tank
Coagulant Solution Tank
5′9″
Dissolving Rack
1″ Galv. Pipe
2 Perforated Spray Pipes
Hand Rail
Up
Up
30′
Perforated Draw-off Pipe
Hand Rail
Manhole
24″ Covers on all Manholes over Roughing Filters
7′9″
4″ Black Pipe from Measuring Box to Lime Water-Tanks
Gauge Tubes
20′
Up
Slaking
4′
Box
18′
13″ Covers on all Manholes in this Room
7′9″
Lime-Water Tank
6′6″
51′
FLOOR PLAN OF OPERATING
OF ROUGHING AND SLOW-FILTER
ROOMS, MACHINERY ROOM
COAGULANT STORAGE RO

unless the lime be added as cream of lime. In the Steelton plant the apparatus is designed to make use of a saturated solution of lime-water.

The lime is slaked in a reinforced concrete box supported on top of the partition separating the two lime-mixing tanks, a sluice-gate being provided on each side for emptying the milk of lime through funnels into pipes leading down to the bottom of the lime-mixing tanks. The latter are rectangular in plan, the bottom of each being in the form of an inverted frustum of a pyramid. From the bottom of each a pipe leads to the sewer, with a connection immediately below the bottom of each tank leading to the lime-water measuring box which stands on brackets above the coagulant-mixing tanks and receives its water through a float and lever valve (with spindle and float as described for the coagulant orifice box) either from the city mains or from a 2-in. centrifugal pump taking its suction from the channel containing the rough-filtered water. Valves in the various pipes permit of cleaning the tanks and pipes, and the admission of water to either of the tanks as desired. The lime-water orifice box is also of reinforced concrete, with a plate-glass front, ½ in. thick, 20 in. wide and 28 in. long, containing two ½-in., two 1-in., and one 1½-in., orifices; there is also a graduated scale etched on the back of the glass, the details of the arrangements being similar to those for the coagulant orifice box. The effluent from the solution-measuring box issues vertically into the mixing tanks through the center of the bottom, rising as a saturated solution through the milk of lime, which has been mixed and deposited in the bottom of the tank. The quantity of water rising through the tank is varied from time to time in accordance with the different conditions of the raw water and the varying consumption of water by the borough, the maximum rate, for a dose of 2 gr. per gal., for a consumption of 3 000 000 gal. daily with both tanks in service, being such that the water would rise through the tanks at the rate of 7 in. per hour if the outlet valves were closed. The water, having picked up its lime at the bottom of the tank, is skimmed off just below the surface by a system of perforated, horizontal, galvanized-iron pipes.

Application of Chemicals.—For mixing the lime-water with the raw water, six lines of 1½-in. galvanized-iron pipes, perforated with double rows of $\frac{5}{16}$-in. holes 3½ in. apart, screwed into a 4-in. galvanized-iron manifold connected with a loose-sleeve joint to the lime-water

supply pipe, lie between the wooden bars of the screen at the entrance to the deposit chamber. The copper pipes for distributing the coagulant solution consist similarly of six lines of 1-in. pipes perforated with double rows of $\frac{3}{16}$-in. holes spaced $3\frac{3}{8}$ in. apart and fastened to a $2\frac{1}{2}$-in. copper manifold; they lie vertically below the lime-water mixing pipes.

Roughing Filters.

The raw water, after passing through the deposit chamber, or in case it is by-passed around the deposit chamber, enters a channel, running lengthwise along one side of the deposit chamber from the

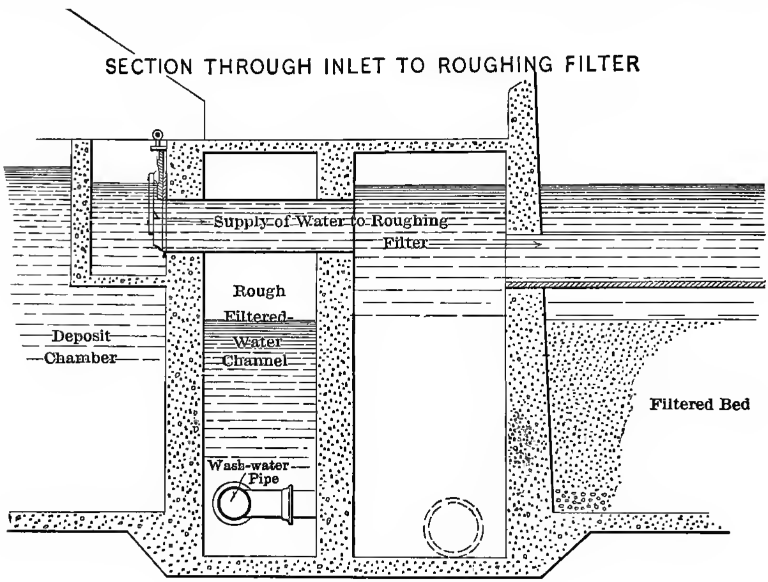
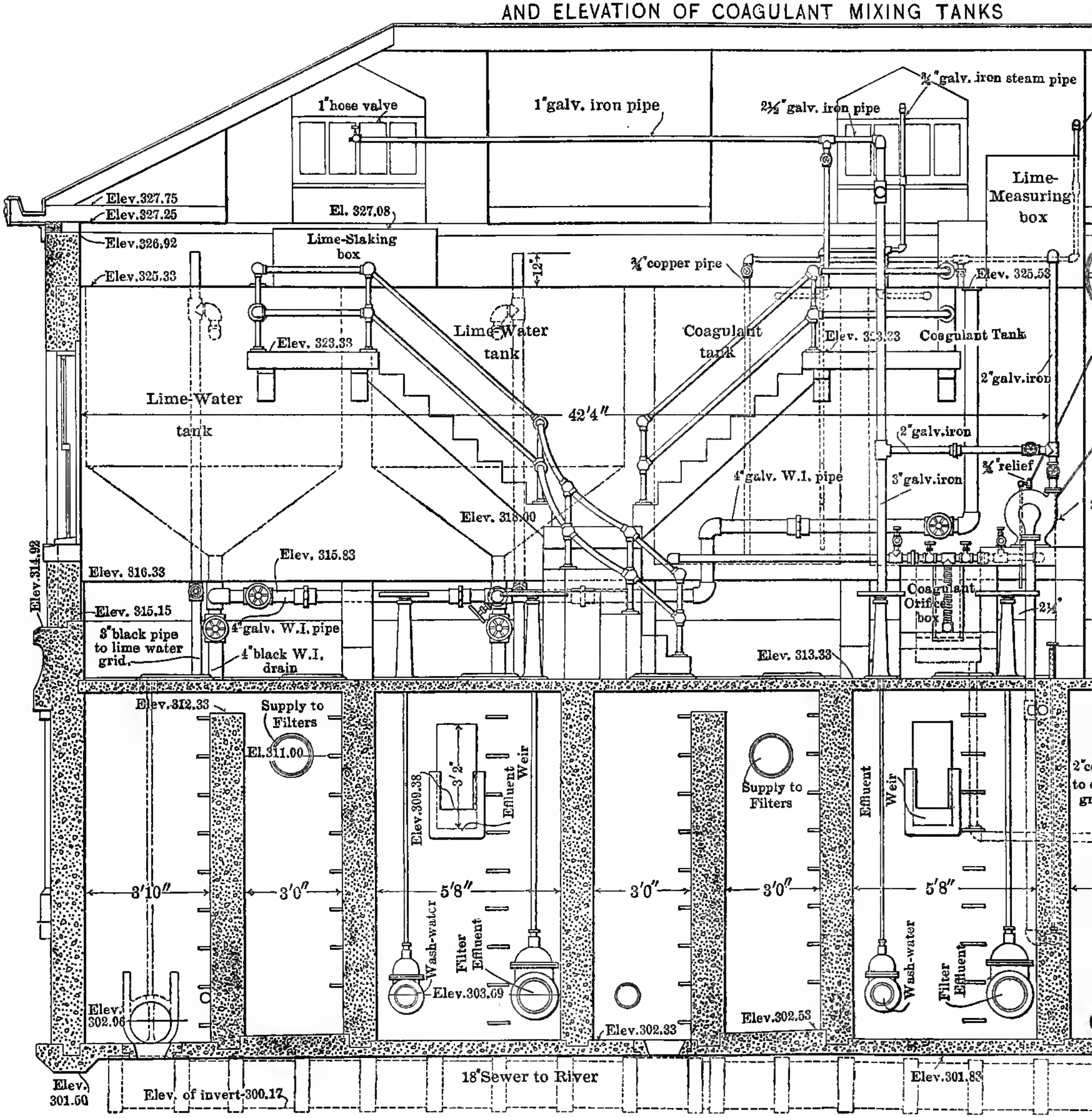


Fig. 2.

weir at the east end to the entrance chamber at the west end, the side and bottom of this channel being supported by vertical steel bars built in the concrete and passing continuously through the side of the channel and the beams spanning the deposit chamber and carrying the mixing tanks. From this channel, Plate XLVII, the water is taken to each of the three roughing filters through 16-in. cast-iron pipes controlled by 16-in. sluice-gates operated with chain-hoists. Between the ends of the three filters and the east side of the deposit chamber are arranged a series of chambers, three for each filter, containing connections to the sewer, to the filtered-water effluent pipe, and to the raw-water supply, a connection being made at the bottom, between this

SECTION THROUGH REGULATING WELLS OF ROUGHING FILTERS
AND ELEVATION OF COAGULANT MIXING TANKS



latter chamber and the chamber leading to the sewer, the purpose of which is to permit the dirty water resulting from the washing of the filters to flow backward through this inlet chamber to the sewer leading to the river. Between the row of regulating chambers for the filters and the deposit chamber is a narrow channel, 3 ft. wide, and about 10.5 ft. deep, into which the rough-filtered water is discharged from the roughing filters, and from which the supply pipe leads to the slow filters.

The 16-in. supply pipes to the roughing filters cross the channel containing the rough-filtered water, and enter the supply chambers immediately in front of the center of each roughing filter. The wash-water troughs, which serve the purpose of distributing the incoming water over the filters during operation, as well as of removing the wash-water when the filters are being cleaned, are suspended from the roof beams of the roughing filters by 1-in. bolts engaging saddle pieces of flat steel, over the top and under the bottom of the troughs, with jamb-nuts at top and bottom to permit of adjustment.

The roughing filters are each 12 ft. 2 in. wide and 29 ft. 6 in. long at the bottom, the sides and ends battering outward 6 in. in the height of the filter, the outside surfaces of the walls being vertical. The side walls and roofs of the filters are of reinforced concrete, and the bottoms of concrete without reinforcement.

Roughing-Filter Underdrains.—In each filter there is an under-drainage system, similar in principle to that designed by the writer in 1902 for the Harrisburg Filter Plant. It consists of 59 parallel 2-in. galvanized-iron pipes, extending across the width of the filter and drilled along the bottom with ¼-in. holes 3 in from center to center, the pipes entering a manifold made of 12-in. flanged pipe built into the concrete wall on one side of the filter and terminating in the effluent regulating chamber in front of the filter in a 12-in. gate-valve operated by hand from the floor above. The 2-in. galvanized-iron pipes are placed in the filter so that their bottoms stand 1 in. above the floor of the filter, and are surrounded with a 4-in. layer of gravel composed of stones which will pass through a screen having ¾-in. meshes in the clear between the wires and remain on a screen having ¼-in meshes in the clear between the wires, and containing no particles finer than ¼ in. in largest dimensions. Upon this rests a second layer of fine gravel, 3 in. thick, all the particles of which will pass through a screen having ¼-in. meshes, but will remain on a standard brass sieve having

12 meshes per lin. in., and containing not more than 2% of particles which will pass through a standard sieve having 15 meshes per lin. in. These specifications were written for local materials, and might require modification for other materials of different subsiding values.

Filtering Materials in Roughing Filters.—The filtering material in the roughing filters consists of a layer of fine anthracite coal screenings, 5 ft. thick, prepared from particles of fine coal washed down the river from the culm piles of the mines on the North Branch water-shed during floods and recovered from the river in the neighborhood of Harrisburg and Steelton by centrifugal pumps. Considerable care was required in the selection of the raw material, as it was desired that the finished product should have an effective size of about 1 mm. and a uniformity coefficient as low as practicable without making the cost of preparation too great. The material as received at the plant contained considerable moisture in the pile and was prepared by casting over a screen having 4 meshes per in., the actual separation with the wet coal being practically the same as would be obtained by screening the dry material through a sieve having 6 meshes per in. Each of the three filters contains 5 ft. in depth of this screened coal, which, as prepared, has an effective size of 1 mm., a uniformity coefficient of about 2.4, and does not contain more than 2% of particles which would pass through a screen having 30 meshes per in. In preparing the river coal, 144 tons of the finished product, weighing about 53 lb. per cu. ft., was required, to secure which it was necessary to screen 176 tons, rejecting 32 tons of coarse particles.

Roughing-Filter Controller.—The rate of filtration of the roughing filters is controlled by regulating the depth at which the rough-filtered water flows over the edge of standard bronze weir-plates, 12 in. long, Plate L and Fig. 3, the weirs being placed in orifices in the front walls of the effluent regulating chambers of the filters, the rough-filtered water falling over the weirs and into its channel, from which it is conducted to the slow filters, the elevation of the weirs being fixed so as to allow losses of head up to about 2½ ft.

Loss-of-Head and Rate Gauges.—The rate of filtration and loss of head are indicated, for each filter, by gauges and indexes operated by spherical, seamless, spun-copper floats, resting on the water in three 8-in. spiral riveted tubes, Plate XLVII and Fig. 3, placed in the regulating chamber of each roughing filter.

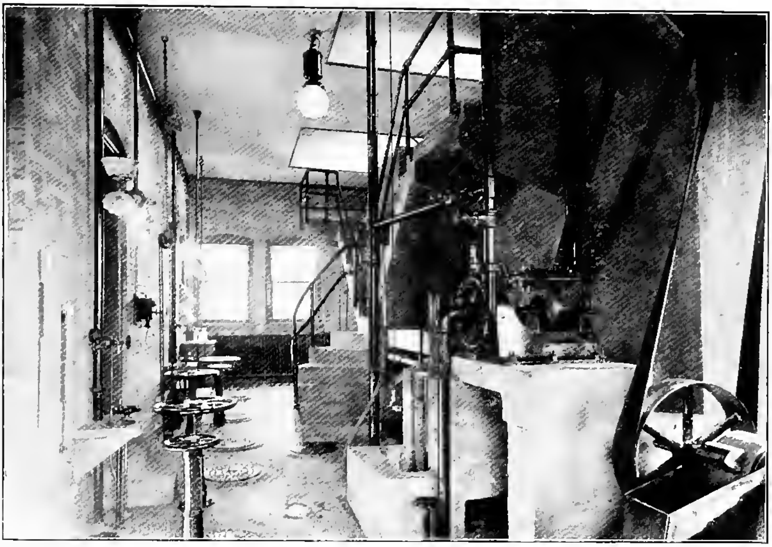


FIG. 1.—ROUGHING-FILTER OPERATING ROOM.

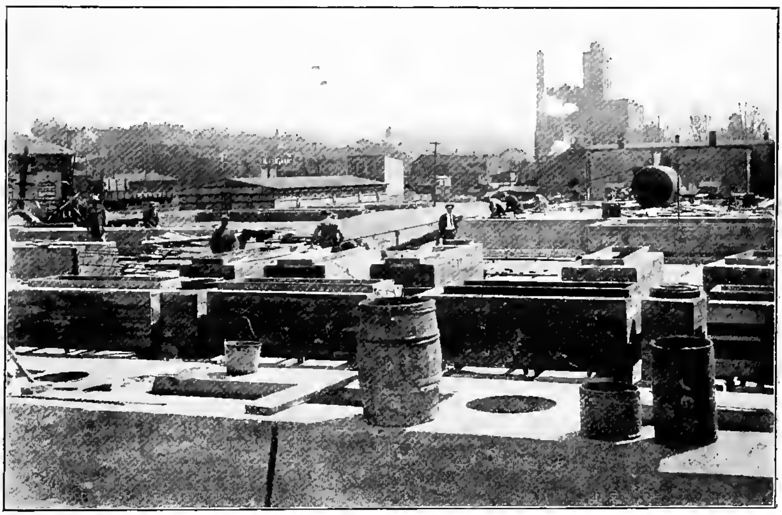


FIG. 2.—FORMS FOR ROOFS OF SLOW FILTER.

The rate gauge was graduated at the plant from the actual measured discharge over each weir in stated periods of time, and at different depths of flow, as indicated by the float gauge. The loss-of-head gauge was divided into feet and hundredths.

The gauge boards were made of strips of poplar, painted with three coats of white-zinc paint, graduated by hand with indelible India ink, the figures and letters being lead pattern-makers' letters attached to the gauge boards with shellac, on the first coat of paint, and painted white with the board before the latter was graduated. After graduation the tops of the letters were blackened, and the board was given two coats of spar varnish and stiffened by small brass cleats

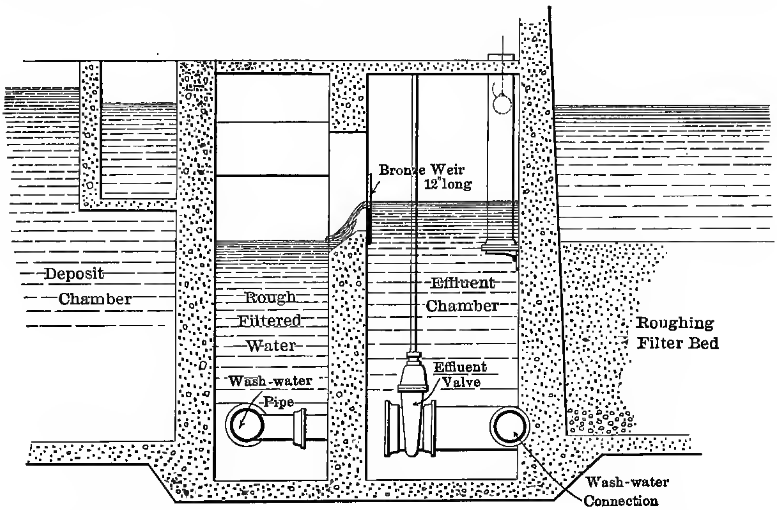


FIG. 3.

screwed to the backs at the top and bottom, the cleats being provided with ears on each side drilled with holes, $\frac{1}{24}$ in. in diameter, parallel to the back of the board and lengthwise of the same. The gauges were strung on parallel guides formed of No. 20, B. & S. gauge, phosphor-bronze wire fastened to screws at the top and bottom in the head and foot blocks.

Roughing-Filter Washing Devices.—Provision for washing each roughing filter was made through an 8-in. connection with a 12-in. pipe laid especially to bring filtered water to the filter plant from the force main leading from the city pumping station to the service reservoir, with a cross-connection also to the 16-in. return main, so that

water may be drawn from either one or the other of these two pipes as desired. The 12-in. pipe divides, on reaching the filter plant, an 8-in. branch, Plate XLVII, entering the roughing-filter plant at the bottom of the channel which receives the rough-filtered water, with connections with the underdrain of each filter back of the effluent control valve, each of these connections being controlled by its own valve operated by a hand-wheel from the operating floor above. In addition, one other 8-in. branch is taken off from the 8-in. wash-water main and terminates in the sewer chamber of the central filter for use in flushing the sewer, if necessary.

In addition to the wash-water, provision is made for scouring the beds of the roughing filters with air admitted to the underdrains through 2-in. galvanized-iron pipes leading from the air receiver and provided with control valves and pressures gauges. The air pipes connect with the wash-water pipes in the bottom of the filtered-water effluent chamber of each filter between the wash-water control valve and the effluent underdrain.

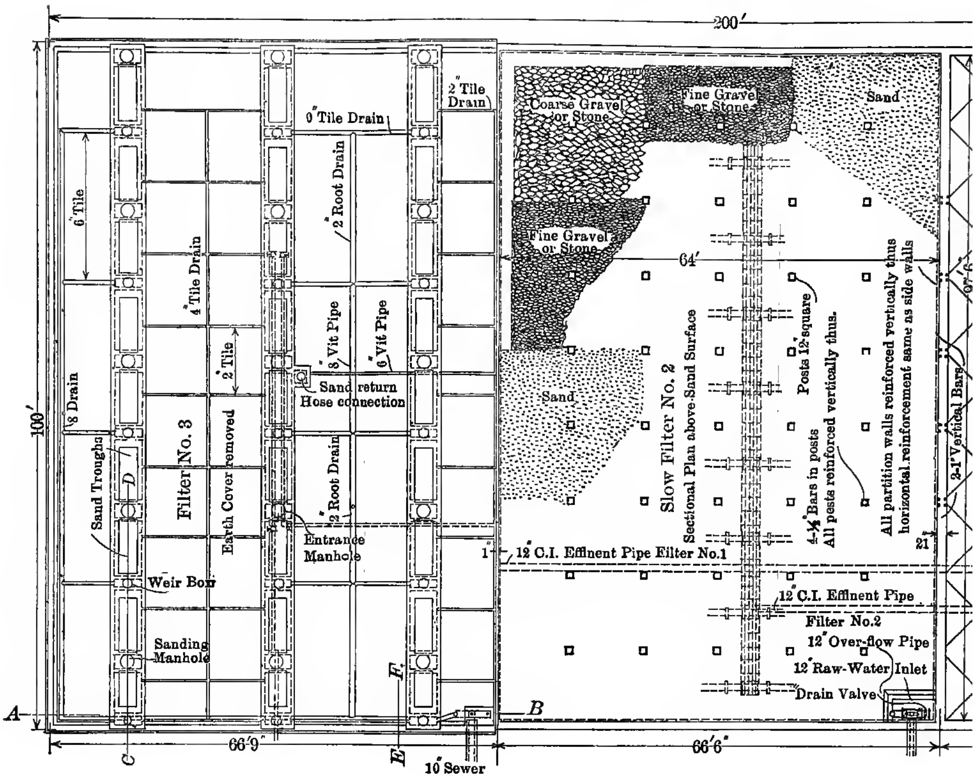
Sewer Connection.—Under the regulating chambers of the roughing filters there is an 18-in. vitrified pipe sewer, Plates XLVII and L, laid in concrete and extending to the river, a distance of approximately 1 000 ft. Into this sewer all parts of the plant can ultimately be drained.

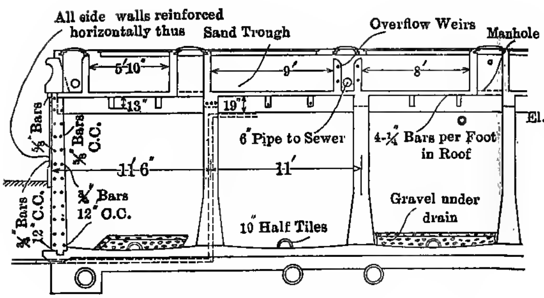
The floor of the operating room of the roughing filters forms the roof over the various regulating chambers and the channel for the rough-filtered water; and the manholes providing for entrance into the various chambers are covered with light, 20-in., circular, cast-iron covers with ring-frames built into the concrete, manhole steps being provided in the walls.

General Water-Supply Pipes.—The water supply for mixing the coagulant solution, for supplying the steam-heating plant, the toilets, and the sand-washer plant of the slow filters, is taken from the 8-in. wash-water main in the effluent channel of the roughing filters by a vertical 3-in. galvanized-iron pipe rising above the ceiling of the operating room and extending lengthwise of the roughing filters to the sand-washer room in the second story of the building over the regulating chambers of the slow filters. The branches for the different fixtures are taken from this main line where required.

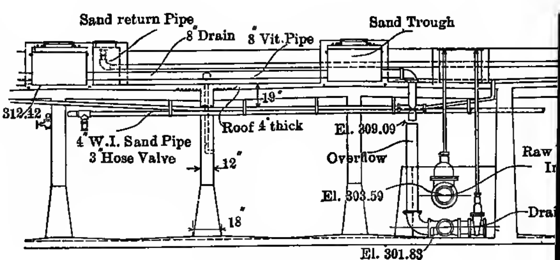
Operating Platform for Chemical Tanks.—From the floor of the operating room of the roughing filters, reinforced concrete stairways,

SLOW FILTERS





SECTION ON *C-D*



SECTION ON *A-B*

Plate L, lead up on either hand to the elevated platform in front of the coagulant-mixing tanks, and the lime-water mixing tanks. These are provided with iron-pipe railings, painted black and varnished.

Centrifugal Pump.—The centrifugal pump, Fig. 1, Plate LI, which supplies the water through the measuring box to the lime-mixing tanks, has a 2-in. discharge pipe, and a 2-in. suction pipe, extending down into the channel containing the rough-filtered water, having on its lower end an elbow, short nipple, and gate-valve with extension stem reaching up above the floor of the operating room and there provided with a hand-wheel. Just below the floor level of the operating room a 2-in. horizontal branch extends through one of the roughing filters to the slow-filter operating room where a hose-valve for 2-in. suction hose is provided in order to permit of using the centrifugal pump to empty the regulating wells of the slow filters below the elevation to which they could be drained naturally.

Electric Motors.—Power to operate the machinery in the plant is derived from the electric current supplied by the York Haven Power Company, and is of the alternating-current type delivered at a voltage of 220 at the switch-board. The motors, Plate XLIX, of which there are two, manufactured by the Westinghouse Electric and Manufacturing Company, one of 5 h.p. and the other of 15 h.p, are of the alternating-current type, wound for 3-phase, 60-cycle, 200-volt terminal voltage, capable of standing an overload of 25% for 2 hours without injury, and provided with oil-immersion starting boxes. A marbleized-slate switch-board, mounted with volt meter, ampere meter, watt meters, circuit breakers, ground detectors, pilot lights, clock, and main and circuit switches for the different services required, stands in the machinery room.

Lighting.—All the filters and different parts of the plant are provided with electric light fixtures wherever light may be required, and all the rooms of the building containing the machinery and the regulating chambers of the different filters are also provided with gas jets.

Air Compressor.—The air compressor for supplying compressed air for scouring the filtering materials in the roughing filters, and for agitating the coagulant solution, stands between the two motors, and can be operated from either one. It is an Ingersoll-Rand compressor, known as the Imperial Type 11, and consists of two cylinders standing vertically, with single-acting plungers driven by crank shafts on opposite sides of a heavy fly-wheel which also serves as the belt pulley.

There is provided on the outlet from the compressor an unloading device, so-called, which, when the pressure reaches the maximum for which the machine is intended, allows the excess pressure to be relieved automatically.

The air compressor has a capacity of 39 cu. ft. of free air per min. at a speed of 200 rev. per min., and is capable of delivering the air at that rate under a pressure of 100 lb. per sq. in. The air cylinders are water-jacketed, with hooded ends, the cooling water being discharged into the trough of the filter below; the air valves are of the poppet type, and work vertically.

Air Receiver.—A 2-in. galvanized-iron discharge pipe, with a brass check-valve near the compressor, leads from the compressor to the air receiver, which is a vertical cylindrical tank, with domed ends, 5 ft. in diameter, and 12 ft. high. The shell is of flange-steel, is furnished with a manhole and a cast-iron base, and is proportioned to stand a working air pressure of 110 lb. per sq. in. and remain air-tight under that pressure. The receiver is provided with connections for the 2-in. galvanized-iron discharge pipe from the compressor and the 2-in. galvanized-iron air pipe leading from the receiver to the air wash-pipes of the roughing filters, and has also a 1¼-in drip at the bottom, provided with a double valve.

The receiver is provided with a safety valve set at 105 lb. per sq. in., a gauge to indicate the pressure in the receiver, and a 1¼-in. Foster reducing valve capable of discharging the entire contents of the receiver in 2 min. at a uniform pressure on the filter side of the valve of about 5 lb. per sq. in., the pressure of the receiver falling, at the same time, from 100 to about 10 lb. per sq. in.

The two motors, the air compressor, and the air receiver stand on foundations built monolithic with the roof of the west roughing filter, and no vibration is apparent when these machines are operating.

Countershaft.—The countershaft to which the motors and air compressor are belted is provided with a jaw coupler between the belt pulleys from the two motors, and is extended through the south wall of the machinery room into the regulating room of the roughing filters, Plates XLVIII and L, where additional countershafts are installed in order to reduce the speed as required for the operation of the grit elevator, and to increase the speed for the operation of the centrifugal pump supplying the water for the lime-water solution.

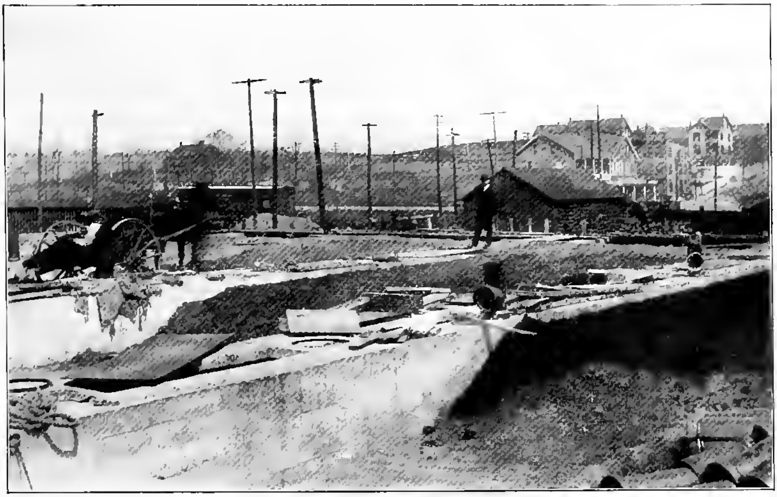


FIG. 1.—TOPS OF SLOW FILTERS DURING PLACING OF EARTH AND TOP-SOIL COVERING.

FIG. 2.—INTERIOR OF SLOW FILTER, SHOWING PLACING OF UNDERDRAINS AND GRAVEL LAYERS.

Superstructure.—The building covering the operating room of the roughing filters, the coagulant storage room, the machinery room, and the regulating room of the slow filters, Fig. 2, Plate LIV, is L-shaped, one leg of which is 44 and the other 65 ft. long, measuring on the long sides, the two wings being, respectively, 21 and 26 ft. wide. The outer faces of the side walls are of red brick, white brick being used on the inside faces. The building is surmounted by a slate roof on a timber framing, with copper ridge, finials, gutters, and down-spouts, the down-spouts discharging into the troughs of the roughing filters, or into the deposit chamber, as necessary.

Sampling Devices.—In front of each roughing filter, and by the side of the entrance chamber for raw water, a small concrete bracket, Fig. 1, Plate LI, and Fig. 1, Plate LV, containing a copper funnel in the center, is fastened to the wall, and carries a nickel-plated goose-neck on the discharge pipe of a small rotary hand-pump, the mechanism of which is submerged in the water immediately below the shelf. The pumps are operated by extension shafts carrying nickel-plated hand-wheels. These pumps are used for obtaining samples of the raw water as it enters the plant and of the effluent from each roughing filter.

Slow Filters.

The rough-filtered water is conducted to the slow sand filters through a line of 16-in. wood-stave pipe with 12-in. connections to each slow filter, controlled by sluice-gates with stems extending to the tops of the filters under a manhole.

Area.—The slow filters, Plate LII, and Fig. 2, Plate LIV, of which there are three, with a total net area of filtering surface of 0.4340 acre, lie side by side immediately north of the roughing filters. They are each 97 ft. 6 in. long, the two end filters being 64 ft. 7½ in., and the central filter, 64 ft. 9 in. wide, all dimensions being measured inside at the bottom, and all interior wall surfaces battering out toward the top 6 in. in their height. The thickness of the outside walls of the filters is 15 in. at the bottom, and 9 in. at the top; the thickness of the division walls is 21 in. at the bottom and 9 in. at the top. The walls are reinforced horizontally and vertically to take the necessary strains, and are built in sections ending against headers, with copper strips in all vertical joints to cut off any possible leakage at such points.

The floors of the filters are laid in blocks, and form inverted groined arches, with the columns supporting the roof standing on the high points.

Roof, Side Walls, and Floors.—The roof of each filter is supported on forty reinforced concrete posts, 12 in. square from the roof to a point $4\frac{1}{4}$ ft. from the bottom, battering out to a width of 18 in. on each side at the floor level. Longitudinally of each filter, reinforced concrete beams, 19 in. deep, run across the tops of the columns in alternate rows, while transversely of the filters, beams, 12 in. deep, run across the tops of all the columns in each row; on the intermediate lengthwise rows of columns the functions of beams for carrying the roof are performed by the deep sides of the troughs intended for the storage of sand removed from the filters during the periodical scrapings, the roof of the filter and the intersecting roof beams being tied to, and suspended from, the side walls of these troughs by vertical steel rods.

The reinforcement of the side walls of the filters consists of three vertical 1-in. bars, opposite each panel point of about 11 ft., running from top to bottom of the wall, the horizontal reinforcement consisting of $\frac{3}{4}$-in. bars, 12 in. from center to center, for the lower 8 ft. in depth, and $\frac{5}{8}$-in. bars, 12 in. from center to center, for the remainder of the height, bars being used in both faces of each wall. The side walls rest in grooves formed along the outer edge of the floor slabs when the latter were laid. In laying the floor slabs, no particular precaution was taken to prevent leakage, further than to form grooves in each side of each slab as it was laid, allowing plenty of time for the concrete to harden and contract, before laying the next slab against it, and using a grillage of $\frac{1}{2}$-in. bars, 4 ft. long, in the concrete of the floor under the bottom of each post supporting the roof. The grooves in the edges of the floor blocks were made V-shaped so that the settlement of any particular block would tend to wedge the joints tight.

Sand Troughs.—The sand troughs, Fig. 2, Plate LI, and Fig. 1, Plate LIII, on top of the filters, of which there are three to each filter, are divided by cross partitions into boxes from 8 to 9 ft. long, separated at one end by weirs and at the other by manholes opening into the filter. The boxes are arranged so that the weirs of two adjacent boxes stand 12 in. apart, forming a channel crosswise of the sand box, from one end of which leads a 6-in. drain-tile connecting with a

FIG. 1.—INTERIOR OF SLOW FILTER, SHOWING SAND IN PLACE.

FIG. 2.—TOPS OF SLOW FILTERS, SHOWING SAND TROUGHS.

system of drains running over the tops of the filters and discharging to the sewer through the overflow of each slow filter. The sand boxes have covers of ¼-in. checkered steel plates stiffened by angle irons riveted to the underside thereof, the cover-plates being in two halves for convenience in handling. Manhole heads and covers, 18 in. in diameter, are provided for the compartments containing the weirs, and 24-in. heads and covers for the manhole opening into the filter, except for the main entrance, for which there is a rectangular checkered steel cover, 2 by 4 ft. The sand boxes have 2-in. drain-tile connections at the bottom of each, and lead into the 4-in. tile drains between two adjacent rows of sand boxes; these connections allow the water to drain out of the sand when the box is filled from the sand-washing plant.

Frost Proofing.—Around the periphery of the plant a curb, 2.5 ft. high, of ornamental design was built on top of the roofs of the filters, and the entire roof, after the pipe drains were laid, was covered with earth, Fig. 1, Plate LIII, to a depth of 2.5 ft., the upper 9 in. being of top soil. The whole area was then raked over and sowed with grass seed.

Exterior Finish.—The visible exterior faces of the slow filter walls were divided into panels by pilasters moulded monolithic with the walls, the effect being carried around the roughing filters as a water-table from which to start the brickwork of the building containing the regulating rooms, storage rooms, etc.

Supply and Drain Valves.—In the southwest corner of each of the three slow filters is a compartment, Plate LII, the top edge of which is level with the surface of the sand. The rough-filtered water is delivered to the filters through these compartments. Drains for emptying the water from the surface of the filters, and overflow pipes connecting with a 12-in. drain, lead to the sewer. The drains from the sand troughs on the roof discharge vertically downward into the overflow pipe.

Slow-Filter Underdrains.—The underdrainage system of the slow filters consists, Plate LII, and Fig. 2, Plate LIV, of lines of 10-in. half-tiles lying at right angles to the length of the filter in the center of each panel between the rows of posts, and connecting with a main underdrain running lengthwise of the filter in one of the panels adjacent to the center line; a 12-in. cast-iron pipe leads from

this central drain to the regulating house. The effluent control valves for all three filters are placed in a special house forming a part of the structure standing on the roughing filters. The half-tile drains were extended to a point about 4.5 ft. from the walls, all around, the ends being closed, and where they cross the central underdrain they were covered with concrete slabs forming part of the tight cover of the main underdrain. The vitrified hub and spigot tile drains were laid with open joints, and were surrounded with layers of broken stone, the first or bottom layer, about 6 in. thick, being composed of fragments of crushed sandstone the largest pieces of which were not more than 3 in. in diameter and the smallest not less than ¾ in. in diameter; the second layer, 3 in. thick, was formed of sandstone particles from ¼ to ¾ in. in diameter, from which the dust had been removed and in which there were few particles larger than ½ in. in diameter; and the top layer, also 3 in. thick, was prepared from sandstone screenings, from which the dust had been removed and in which there were no particles larger than ½ in. in diameter and very few larger than ¼ in. in diameter. The material was secured from a quarry at Marysville, on the Susquehanna, some miles above Harrisburg, and was in three sizes, ¾ in. to 3 in., ¼ to ¾ in., and screenings, the latter containing a considerable quantity of fine dust as well as particles up to ¾ in. in diameter. By proper sorting the only material requiring a second handling was the screenings, which, on sifting through ¼-in. and ¾-in. sieves, provided for all the fine material and for nearly one-half the ¼ to ¾-in. gravel required; but the weight of the wasted dust from the screenings exceeded, by approximately 25%, the weight of the useful materials secured. As received at the works, the materials were quite dirty, and a simple plan for washing out the stone dust was devised by the contractor's foreman. This consisted of a couple of oil barrels mounted tandem on horizontal axes slightly above the centers of the barrels, on a framework high enough to allow a dump-cart to stand thereunder. The two barrels were provided with a simple lever arrangement for turning them upside down. After being filled with water from a hydrant, they were suddenly upset on a cart containing, perhaps, ½ cu. yd. of broken stone. This quick flush effectively washed the mud from the whole depth of stones in the cart, the surplus water draining out under the tailboard.

The gravel underdrains were not carried out to the side walls of the

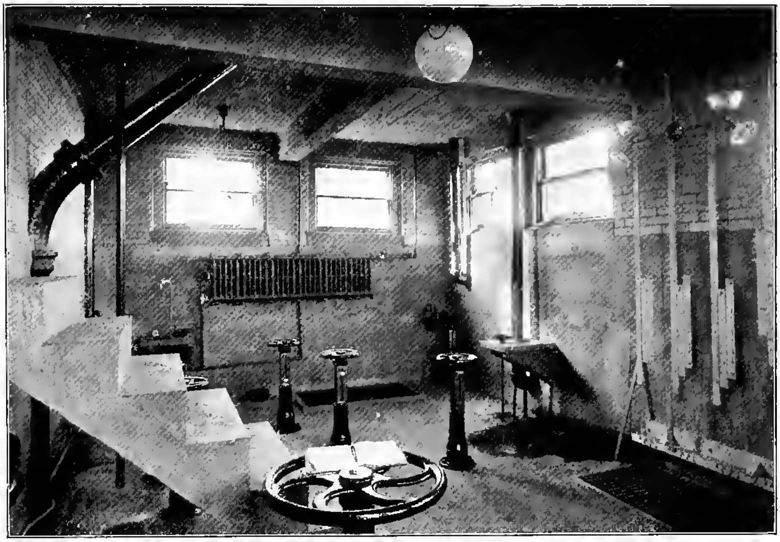


FIG. 1.—SLOW-FILTER OPERATING ROOM.

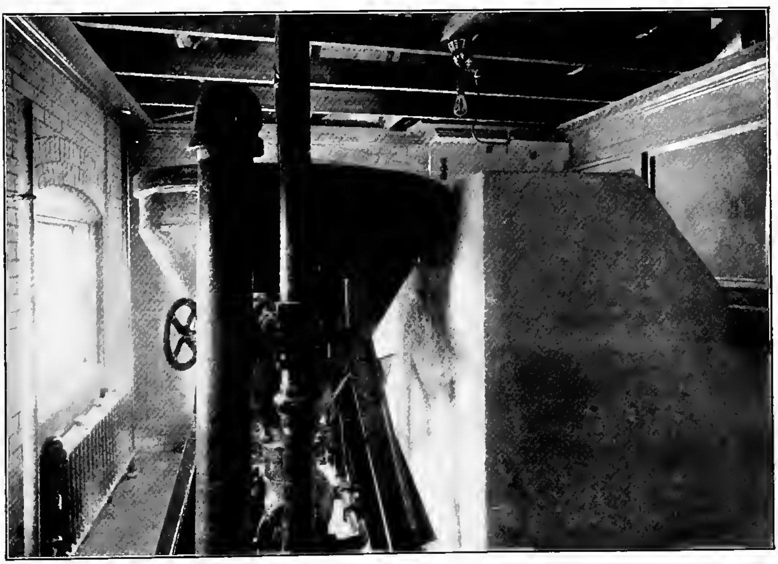


FIG. 2.—SAND WASHER.

filter, but were stopped about 2 ft. therefrom and banked up to the proper height, the finer layers of gravel covering the coarser layers on the slopes, and the top surface being brought to a uniform level.

Filter Sand.—The filter sand was secured from the Susquehanna River, and required no further preparation than screening, and, at times, the mixing of sands obtained from different localities.

The specifications for the sand were as follows:

Not more than 10% should be smaller than 0.29 mm. in diameter.
Not more than 5% should be smaller than 0.24 mm. in diameter.
At least 90% should be finer than 0.80 mm. in diameter.

Practically all the particles should be finer than 1 mm. in diameter, and the uniformity coefficient should be not greater than 1.6 to 1.8.

These specifications were written for the Susquehanna River sand with which the writer had had much experience; a modification of these requirements might be desirable for sands from other localities.

As to chemical composition, the Susquehanna River sands were satisfactory, containing less than 2% of lime and magnesia, and less than 5% of an aggregate amount of iron and aluminum in forms likely to disintegrate under the action of water or chemical changes produced by matters the water might contain when passing through the sand. The analyses of the samples of sand taken after the filters were ready to be put in operation are given in Table 1.

Filter No. 3 and practically all of Filter No. 2 were filled with sand obtained at Northumberland, from the West Branch of the Susquehanna, and required no further preparation than the careful selection of the barge loads as the sand was dredged, accepting those which would fill the requirements satisfactorily, as indicated by field tests conducted as the dredging proceeded, and rejecting those in which the sand was too fine or too dirty. The only difficulty experienced with this sand was the likelihood of its containing noticeable quantities of saw-dust, shreds of bark, and friable particles, but casting it by hand over screens having ¼-in. meshes removed the objectionable matters to a degree which rendered the sand satisfactory for filtration purposes.

Owing to the frequent changes in the conditions of flow in the Susquehanna, the character of the sand deposited is subject to variation, and, before a sufficient quantity had been secured, the Northumberland deposits had become too fine for use and it was necessary

to seek a coarser sand to mix with it in order to increase its effective size. An inspection of several deposits farther up the river finally disclosed one at Nesbit, from which much of the finer material had been washed, and by combining the mechanical analyses of this and the Northumberland sands, it was found that a satisfactory composite sand could be made by mixing the two in proper proportions.

TABLE 1.—Mechanical Analyses of Sand in Slow Filters of Steelton Filter Plant.

Note.—In this table the figures in Column 1 give the depth from which the sample was taken, those in Column 2 refer to samples collected on the northeast corner of the filter, those in Column 3 to samples of the southeast corner, those in Column 4 to samples collected in the center of the filter, those in Column 5 to samples collected in the northwest corner of the filter, and those in Column 6 to samples collected in the southwest corner of the filter.

(1)	(2)		(3)		(4)		(5)		(6)	
	Northeast Corner.		Southeast Corner.		Center.		Northwest Corner.		Southwest Corner.	
Depth from which sample was taken.	Effective Size.	Uniformity Coefficient.	Effective Size.	Uniformity Coefficient.	Effective Size.	Uniformity Coefficient.	Effective Size.	Uniformity Coefficient.	Effective Size.	Uniformity Coefficient.
Filter No. 1.										
Top 0.5 ft.	0.32	1.7	0.32	1.5	0.32	1.7	0.31	1.5	0.31	2.0
0.5 to 1.5 ft.	0.30	1.8	0.30	1.6	0.31	1.7	0.31	1.6	0.31	1.9
1.5 to 3.0 ft.	0.29	1.9	0.32	1.5	0.32	1.5	0.30	1.6	0.32	2.0
3.0 to 4.0 ft.	0.31	1.5	0.33	1.3	0.29	1.7	0.31	1.6	0.32	1.8
Filter No. 2.										
Top 0.5 ft.	0.32	1.5	0.30	1.5	0.30	1.4	0.31	1.4	0.30	1.4
0.5 to 1.5 ft.	0.32	1.5	0.30	1.5	0.30	1.4	0.30	1.5	0.30	1.4
1.5 to 3.0 ft.	0.30	1.4	0.31	1.4	0.30	1.5	0.31	1.4	0.30	1.4
3.0 to 4.0 ft.	0.31	1.4	0.40	1.3	0.31	1.4	0.30	1.4	0.29	1.5
Filter No. 3.										
Top 0.5 ft.	0.31	1.6	0.30	1.8	0.31	1.8	0.31	1.7	Samples not taken.	
0.5 to 1.5 ft.	0.32	1.6	0.30	1.8	0.33	1.7	0.29	1.8		
1.5 to 3.0 ft.	0.32	1.6	0.29	1.7	0.36	1.5	0.30	1.8		
3.0 to 4.0 ft.	0.31	1.7	0.32	1.7	0.36	1.5	0.28	1.8		

As an example, Table 2 exhibits the analyses of the Northumberland and Nesbit sands on July 2d, 1908, at which time the mixing of the two sands in equal proportions produced the desired composite.

TABLE 2.

Sieve: Meshes, per inch.	Size of separation of sieves, in millimeters.	Nesbit sand. Percentage passing sieve.	Northumberland sand. Percentage passing sieve.	Composite sand. Percentage passing sieve.
20	1.02	100	100	100
30	0.57	64	65	65
50	0.38	8	23	13
60	0.29	2	14	7
80	0.21	0.3	0.6	0.5
Effective size		0.4 mm.	0.27 mm.	0.32 mm.
Uniformity coefficient		1.4	2.00	1.6

When Filter No. 1 was being filled, the Northumberland sand had an effective size of only about 0.27 or 0.28 mm. The two sands were mixed by dumping cart loads of each kind upon separate platforms on each side of a manhole, and casting simultaneously the correct relative numbers of shovelsful from each pile upon a screen standing over the manhole. In passing through the screen and falling to the filter below, the two sands became thoroughly mixed, as will be seen from an inspection of the analyses in Table 1.

The sand was delivered to the filters in one-horse, two-wheeled carts. It was dumped through the manholes, and spread in three layers, care being taken not to compact it unevenly. The top surface, Fig. 1, Plate LIV, was leveled off with straight-edges to a practically uniform elevation, the final operation being to rake the entire area over lightly with an iron rake. A typical mechanical analysis of the Northumberland sand, when running at its best, is given in Table 3.

The Northumberland sand, during the process of dredging from the river bottom, was quite thoroughly washed, and required no further treatment except screening through ¼-in. mesh screens to remove mussel shells, shreds of bark, etc., before being placed in the filters.

The total quantity of sand shipped to Steelton for the slow filters was 3 989 tons, in 107 car loads, and made, in the filters, 2 953 cu. yd.

In order to help out the contractor in the matter of securing this

sand, the writer kept an inspector at the sand dredges, whenever sand was being secured, during the entire period covering November and December, 1907, and January, April, May, June, and July, 1908; actual dredging operations, however, were limited to 92 days during this time.

TABLE 3.—MECHANICAL ANALYSIS OF SAMPLES OF NORTHUMBERLAND SAND, OCTOBER 31ST, 1907.

Size of sieve. Meshes, per linear inch.	Effective size of separation, in millimeters.	Weight of sand passing sieve, in pounds.	Percentage passing.
4	3.4	2.295	100
10	2.15	2.289	99.7
20	1.02	2.274	99
30	0.57	2.183	95
40	0.45	1.774	76
50	0.38	1.067	46
60	0.29	0.170	7.4
80	0.21	0.025	1.1
100	0.17	0.012	0.6
150	0.12	0.005	0.0

Note.—Effective size, 0.31 mm.; uniformity coefficient, 1.37: finer than 0.24 mm., 2.5%; finer than 1 mm., 99%; finer than 1.5 mm., 99.5 per cent.

The total cost of inspecting the sand, including the salary of the inspector, his board, and traveling expenses, was 9.5 cents per ton, or 13.0 cents per cu. yd. As the sand was running, a satisfactory indication of its character was obtained by a mechanical analysis of one sample to about each 30 cu. yd. dredged. The sand was sampled on the barge before unloading, each sample being a composite of samples collected at about four places from freshly excavated vertical faces in the sand as piled on the barge, and collected so as to be representative of the material for the full depth of the pile. These samples were then thoroughly mixed, the sample for analysis being taken therefrom, dried, and sifted through carefully rated screens.

Sand obtained in the river deposits in the neighborhood of Harrisburg could not have been used without expensive preparatory treatment to remove the fine material, as its effective size usually runs from about 0.23 to 0.24 mm. To remove some of the fine material, washing is necessary, the total waste ranging from about 10% to more than 50%, depending largely on the quantity of coal dust in the sand. The sand from Northumberland, being obtained from the West Branch above the junction of the North Branch, is free from coal, and is also coarser than that obtained farther down the river.

Effluent Control of Slow Filters.—The effluent pipes pass beneath the floors of the slow filters, and each terminates in its own regulating chamber with a sluice-gate controlled from a valve-stand and hand-wheel on the floor of the operating room. The rate of filtration of each filter is controlled by causing the filtered water to flow through a submerged orifice, Fig. 4, 8 in. in diameter in the end of an outlet pipe having a swivel-joint at the lower end, Plates XLVII and XLVIII, and discharging through a gate-valve into a filtered-water well common to the three filters. The free or orifice end of the swivel-

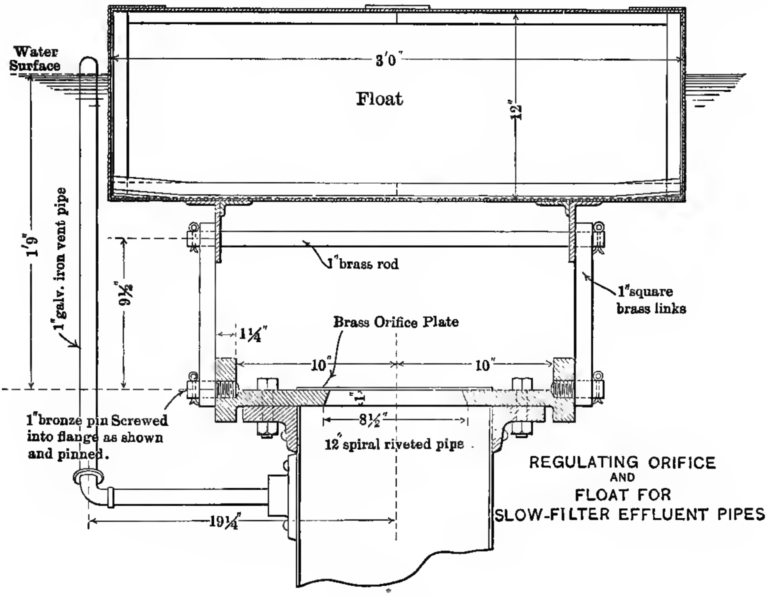


FIG. 4.

jointed pipe is suspended by brass links from a float resting on the surface of the filtered water in the effluent chamber of the filter; the center of the 8-in. orifice is adjusted to stand 1 ft. 9 in. below the surface of the water in the effluent well, at which depth, with a free discharge through the orifice into the atmosphere, the filter will deliver 1 500 000 gal. per day to the outer well. If the pumps in the Borough pumping station do not take the water away as fast as the three filters can furnish it, the water rises in the outer well, submerges the orifices, and cuts down the head by an amount just sufficient to keep up the supply, the plant being capable, therefore, of yielding the water to the

pumping station automatically at any rate necessary, up to the maximum for which the plant is designed, namely, 1 500 000 gal. per day per filter. In order to prevent any draft-tube effect in the effluent pipe, between the effluent well and the outer filtered-water well, a 2-in. galvanized-iron pipe is connected with the swivel-jointed pipe at a point below the orifice, the free end of the 2-in. pipe being adjusted so as to be always above the water level in the effluent well, whatever position the float may take; this assures a discharge into the atmosphere whenever the difference in level of the water between the effluent well and the filtered-water well of any filter exceeds 1 ft. 9 in.

Gauge Boards.—The rate of filtration and loss of head are indicated on scale boards, Fig. 1, Plate LV, carried by bronze wires attached to floats in the different compartments of the regulating house, as described for the roughing filters. A sampling pump, similar to those for the roughing filters and the raw water, is provided for the effluent well of each slow filter.

The filtered water leaves the central filtered-water well through a 24-in. wood-stave pipe leading to the new pump-well at the pumping station, a sluice-gate being provided at each end of this pipe line.

Sand Washer.—The system of handling the sand when the slow filters require cleaning is not new in principle, but the details differ materially from those of other plants. Portable ejectors, supplied with water at about 100-lb. pressure from a line of 4-in. wrought-iron pipe, Plate LII and Fig. 2, Plate LIII, suspended from the ceiling of each slow filter, through 3-in. bronze hose-gates and 3-in. hose, lift the dirty sand and transport it to the sand-washer plant. The dirty sand, having been shoveled into piles in the filter, is cast into the hopper of the portable ejector, is picked up by the jet of water passing through the ejector, and delivered through a line of 4-in. wrought-iron pipe to the sand-washing hoppers, Plate XLVIII, and Fig. 2, Plate LV, in the second story of the slow-filter regulating house. After passing through two hoppers the washed sand is forced by a jet in the bottom of the second hopper through a line of 4-in. wrought-iron pipe, resting on the roof of the three filters, to hose-valves from which lines of hose may be laid to discharge the returning clean sand into the compartments of the sand troughs running lengthwise of the tops of the filters. The operation is simple, and requires no special description or comment.

Heating.—The building covering the operating rooms of the rough-

ing and slow filters, as well as the machinery room and the coagulant-storage and sand-washer rooms, is heated by steam generated in a vertical tubular boiler standing in the second story of the slow-filter regulating house. The returns from the radiators are piped back to a trap in one corner of the slow-filter operating room, and discharge into the sewer. The provisions for heating required boiler capacity with sufficient heating surface and grate area to furnish steam to raise the temperature of 20 000 lb. of coagulant solution from 32° to 70° Fahr., in 1 hour. The boiler is designed to carry 100 lb. of steam, and is provided with a reducing valve, on the steam-heating connection, set at 5 lb. The coils and radiators are proportioned to maintain the machinery and operating rooms at a temperature of 70° and the coagulant-storage room and the sand-washer room at a temperature of 58° when the outdoor temperature is at zero. The toilet-room is provided with a wash-basin with cold-water connection and a steam connection for securing hot water, and a low-down tank closet.

Construction.

No special difficulties were encountered during construction, the bearing value of the foundations proving satisfactory for the relatively light loads they are required to carry. There was comparatively little ground-water in any of the work, although the permanent ground-water level was barely below the floor of the excavation for the slow filters; in fact, a modification of the design of the main underdrains of two of the filters was made necessary in order to keep the work out of the water. A considerable portion of the site of the slow filters was, in early days, a low swale which had been used subsequently as a dumping ground for slag, cinders, and ashes from the steel works, and it was owing to the presence of these materials, which had had such a long time to become thoroughly settled, that satisfactory foundations were secured without extra work.

Leakage.—Before the sand was placed in the slow filters they were filled with water from the street mains up to the level required for operation, the water from the street being then shut off and the drop in the surface level being observed. It was not expected that the filters would be perfectly tight, owing to the construction of the bottoms in blocks about 11 ft. square, with no special provision for stopping leakage between the blocks. The leakage from each of the

three filters was about the same, and aggregated about 0.66 of 1% of the nominal daily capacity of the plant. No tests to determine the amount of leakage have been made since the filters have been in operation, but it is believed that there has not been an increase.

Cost of the Plant.—The plans were completed in July, 1907, and, in response to advertisements, three bids were opened on August 7th, 1907, aggregating \$71 522.85, \$80 482.48, and \$89 592.59, respectively. The contract, which was awarded August 14th, 1907, to the Bunting Construction Company, of Flushing, N. Y., stipulated that the work should be completed within 6 months from the date of the contract, or by February 14th, 1908. Various delays resulted, however, and it was not until the middle of September that the plant could be put in operation, the final estimate to the contractor being dated September 24th, 1908, and amounting to \$70 730.87. This, however, did not represent the full cost of the work, as the installation of the centrifugal pumps, the changing of the suction pipes at the pumping station, and some repair work on the checkered steel covers on the slow filters, were done by the Water Board outside of the contract. In addition to the above items, there were the cost of the site and of engineering and incidental expenses, which were high, by reason of the fact that the time occupied by the contractor in the construction of the plant was more than twice that in which the work should have been completed under favorable conditions.

The following are the principal items making up the cost of the plant:

Excavation, grading, roadways, sodding, etc..	\$3 936.88
Sewers and drains..........................	2 314.67
Concrete, all classes..........................	18 708.32
Reinforcing steel..........................	3 475.80
Manhole heads and covers, indoors and outdoors..........................	1 590.50
Cast-iron pipes and specials..........................	3 956.27
Wood-stave pipes between filter plant and pumping station..........................	9 034.21
Filter regulating devices, gauges, coagulant and lime-water apparatus..........................	2 650.00
Superstructure over regulating houses, etc., including steam heating, lighting, and plumbing..........................	7 900.00

Machinery, plant, motors, compressor, shafting, belting, air receiver, sand-washing plant, etc.	3 750.00
Gate and sluice valves	1 485.00
Filtering materials, including underdrains	10 811.34
Extra work	1 117.88
	$70 730.87

Of the above amount, $57 000.00 is the cost of the purification works, the remainder, $13 700.00, being the cost of the pipes to the pumping station, the sewer to the river and other details growing out of local conditions.

Operation.

The plant was put in service on September 12th, 1908, but was shut down later in the day, and was started again on September 16th, since which date it has furnished filtered water continuously.

The regular force required for operation consists of a general superintendent and two filter attendants, the latter working on 12-hour shifts. When the slow filters require scraping an additional force is taken on temporarily, the men working under the direction of the general superintendent.

The permit for the construction of the plant, issued by the Pennsylvania State Department of Health, provided that the filters should be operated for a considerable period under the direction of its designer, and in compliance with this condition the writer instructed the superintendent and attendants in their duties, provided specific instructions regarding the manipulation of the roughing and slow filters, and the handling of the coagulant, and has advised with reference to special features of the operation whenever necessary.

From September 16th, 1908, until January 9th, 1909, no coagulant was used in connection with the operation of the roughing filters, the raw water being sufficiently free from turbidity to yield a satisfactory water without coagulant.

Quantity of Coagulant Required.—The general instructions given to the superintendent called for the application of a coagulant to the raw water whenever its turbidity exceeded 50 parts per million, and the continuance of its use for much lower turbidities whenever the

last bacterial analyses showed 5 000 or more bacteria per cu. cm. in the raw water, or in case the effluent from the slow filters showed objectionable color. It is the intention, in dosing with coagulant, to use a sufficient quantity to produce an effluent from the roughing filters having a turbidity of not more than 10% of that of the applied water, and not, in any case, more than 25 parts per million, regardless of the turbidity of the raw water. It has also been found desirable, particularly during the winter and the cold spring weather, to manipulate the dose of coagulant so as to produce an effluent from the rough-

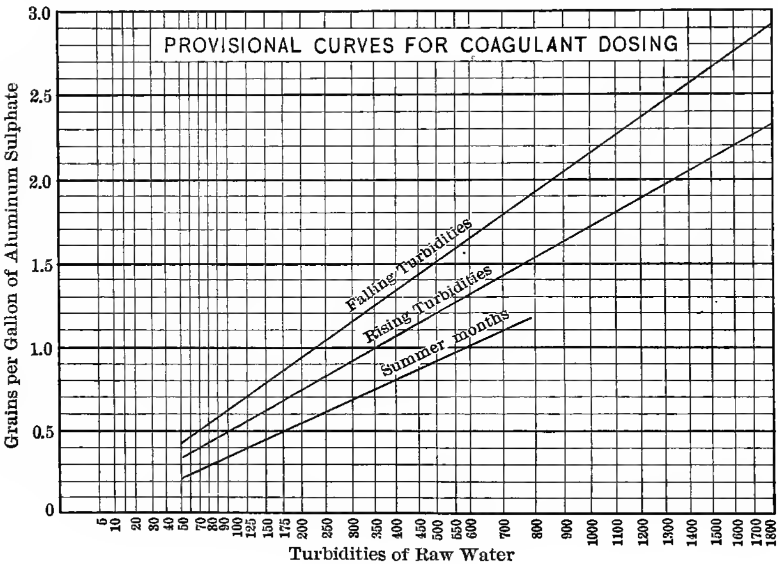


FIG. 5.

ing filters having a turbidity of practically zero, as by this means the runs of the slow filters are very greatly lengthened and the cost of operation is not increased by the use of the comparatively small additional amount of coagulant necessary to secure this result.

The quantity of coagulant to be used is determined by the superintendent from a diagram, Fig. 5, prepared by the writer from data secured originally during the operation of the Harrisburg Testing Station, in 1902 and 1903, but modified somewhat to take into account the difference in the character of the filtering materials, and the slightly different character of the raw water at the Steelton intake; the

diagram may require further modification as additional knowledge is gained during the operation of the plant. The dose of coagulant indicated by the lowest curve is for application during the summer when the turbidities do not rise very high, or very suddenly. The dosing indicated by the middle curve is required when the turbidity is rising rapidly, during the first parts of the floods in the fall, winter and spring; the dosing indicated by the upper curve is required when the turbidity is falling, after the passage of a flood. It will be noticed that for equal turbidities more coagulant is required when the turbidities are falling than when they are rising, on account of the finer character of the turbidity and the persistence of high numbers of bacteria in the Susquehanna after the turbidities have begun to fall. The superintendent must use judgment in determining the proper dose of coagulant. The character of the turbidity of the river water varies so greatly and changes so quickly that a dose satisfactory with a given clay turbidity, say, of 500 parts per million, might prove altogether too much for an equal turbidity from the North Branch. At times, also, particularly after a protracted season of low water, a turbidity caused largely by the fine shreds of vegetation torn and scoured loose from the rocky river bottom is particularly difficult to handle by reason of its high clogging value when it becomes matted upon the filter surface. In order to keep the plant in efficient operation, therefore, the superintendent must watch the effect of his dosing and reduce the quantities if he finds the loss of head increasing on the roughing filters too rapidly, or increase the quantity if the conditions require it.

When to Wash the Roughing Filters.—If, when coagulant is being applied to the raw water in the proper amount, the effluent of a roughing filter shows objectionable turbidity, indicating the passage of coagulated material through the filter bed, the filter is immediately washed; otherwise, it is left in operation until the maximum allowed loss of head, about 2.5 ft., is reached.

This method of operation is based on the theory, which seems to be supported by considerable evidence gained both at this plant and at the Harrisburg Testing Station, that these coarse-grained filters act very much as settling basins with bottom areas of great extent. The mud carried into the filter by the entering water is deposited on the granules of the filter bed through practically its entire depth, and one

of the requirements in controlling their operation is to prevent the washing of this sediment through the filters by pushing their operation too rapidly, or by using too great losses of head, or by suddenly increasing the rates of filtration. To prevent most of these evils the mechanisms at the plant limit the loss of head to about 2.5 ft.

Regulation of Coagulant Dosing.—The quantity of solution required to supply a given dose of coagulant depends on the quantity of water being filtered and the percentage strength of the solution.

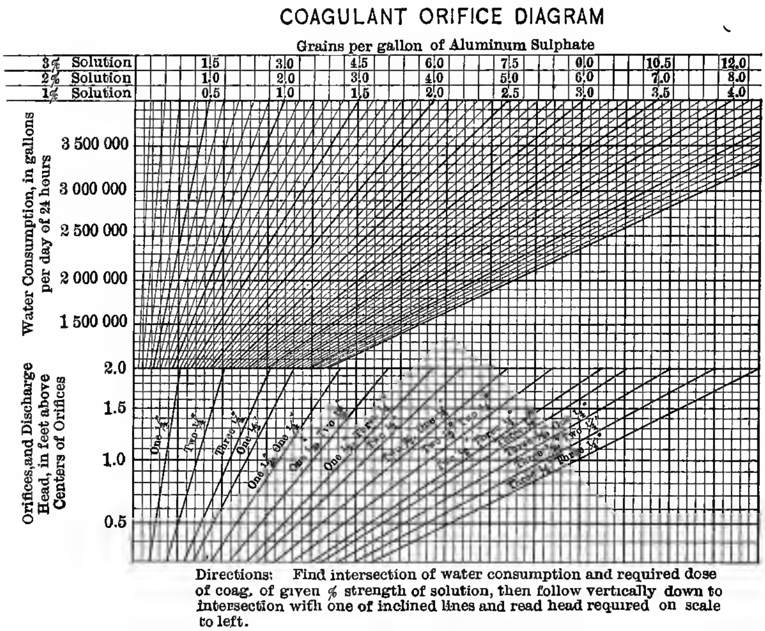


FIG. 6.

Knowing these, the requisite quantity of solution is measured out by continuous discharge through orifices in the glass plate forming the front of the measuring box, the size and number of orifices, as well as the head required to give the necessary dose, in grains per gallon, being ascertained by the superintendent from a diagram, Fig. 6, prepared for his use. The lines indicating the orifices to be used were placed on the diagram in accordance with the measured discharge of each orifice.

Use of Lime-Water.—During floods the alkalinity of the river water

falls sometimes too low to permit of the decomposition of the requisite dose of aluminum sulphate, and provisions are made to add, at such times, sufficient milk of lime to supply the deficiency in alkalinity. When lime must be used, enough is added to neutralize the free CO_2 in the river water, combine with the aluminum sulphate, and leave a residual alkalinity in the water of about 6 parts per million. The free CO_2 and alkalinity are determined by the methods recommended by the Committee on Standard Methods of Water Analysis, of the American Public Health Association. Knowing the dose of aluminum sulphate being used, and having ascertained the alkalinity of the raw water, and the amount of free CO_2 carried, reference to a diagram including all these data will give the quantity of lime required, if any.

Regulation of Lime Dosing.—The quantity of water required to add this dose of lime to the raw water in a saturated solution is regulated at the lime-water measuring box in the manner in which the coagulant dose is regulated, a diagram similar to the coagulant-dosing diagram being supplied for the lime-water. The amount of lime to be slaked daily to produce the required quantity of lime-water, for different dosings and different daily consumptions of water, is determined by the superintendent from another diagram, small quantities being slaked from time to time during the day and discharged as milk of lime through the funnel and pipe leading to the bottom of the lime-mixing tanks. The strength of the lime-water solution is to be tested from time to time by the usual simple chemical test, and it should be kept up to full strength by the attendant.

Another diagram gives the number of pounds of aluminum sulphate required for making solutions of different percentage strength, the capacity of the tanks having been calibrated for the purpose.

Simplicity of the Dosing System.—No calculations being required on the part of the superintendent during the operation of the plant, the rapid changing of the dosing, when required, can be effected with accuracy and without the likelihood of errors from faulty calculations.

The lime-water and the coagulant solution are admitted to the water practically together. The conditions requiring the use of lime being comparatively rare no great pains have been taken to go into refinements in the use of lime that would be desirable under conditions requiring its more continuous use.

Reduction of Alkalinity by Coagulant.—As to the proportion of the coagulant rendered inactive through its absorption by suspended matters in the water, sufficient data have not yet been obtained at the Steelton plant to speak authoritatively, but it is believed, from present indications, that the reduction of alkalinity of the raw water, instead of the theoretical 8.2, will probably be about 6 parts per million, per grain of coagulant used, as observed at the Harrisburg Filter Plant during the past three years and at the Harrisburg Testing Station in 1902 and 1903.

Operation of Roughing Filters.

Operation with Respect to Lengths of Runs.—While the roughing filters must be operated in a manner to secure an effluent sufficiently free from turbidity and bacteria to be handled satisfactorily by the slow filters, their operation must be controlled in a manner to secure sufficiently long periods of operation between washings, otherwise the plant could not be kept going during periods of very turbid water. A little experience is required to enable this to be done, but it presents no practical difficulty with any range of conditions thus far encountered on the Susquehanna at Harrisburg and Steelton. The highest turbidity experienced since the plant has been in operation occurred in the forenoon of January 26th, reaching 1 600 parts per million, remaining at that figure for about 5 hours, and dropping by steps to 500 parts during the next 12 hours. The shortest run during this period was about 2½ hours, which occurred after the turbidity had dropped to about 700 parts. The first turbid water the plant was required to handle occurred about January 8th, at a time when the writer was not able to be present, and, owing to the deterioration of certain of the silica-turbidity standards, the turbidities of the raw water and of the effluents from the roughing filters were incorrectly read, the actual turbidities being much higher than the figures recorded. As a result, the quantity of coagulant used was entirely too small, and a considerable number of bacteria passed through both the roughing filters and the final filters.

Records of Operation.—Since January 23d, 1909, with but very few exceptions, the coagulant has been properly applied, and the satisfactory results obtained in the removal of turbidity are exhibited in Table 4, which gives the hourly records of the operation of Roughing Filter No. 1, through runs Nos. 58 to 81, January 26th to 31st, 1909, inclusive.

TABLE 4.—HOURLY RECORDS OF OPERATION OF ROUGHING FILTER NO. 1 THROUGH RUNS NOS. 58 TO 81, JANUARY 26TH TO 31ST, 1909.

Number of run.	LENGTHS OF RUN.		DATE.		TURBIDITIES, IN PARTS PER MILLION.			Coagulant used, in grains per gallon.
	Hours.	Minutes.	Day.	Hour.	Raw water.	Rough-filtered water.	Percentage of removal.	
58	9	58	Jan. 26	6 A.M.	80	1	98.8	0.42
				7 "	800	1	99.9	0.42
				8 "	800	1	99.9	0.92
59	4	16		9 "	800	1	99.9	1.84
				10 "	1 600	1	99.9	2.22
				11 "	1 600	1	99.9	2.22
				12 M.	1 600	1	99.9	2.22
				1 P.M.	1 600	1	99.9	2.22
60	3	02		2 "	1 600	1	99.9	2.22
				3 "	900	1	99.9	2.00
				4 "	900	1	99.9	2.00
61	2	31		5 "	900	1	99.9	2.00
				6 "	900	1	99.9	2.00
				7 "	800	1	99.9	2.00
62	2	26		8 "	700	1	99.8	1.50
				9 "	700	1	99.8	1.50
63	4	35		10 "	700	1	99.8	1.50
				11 "	700	1	99.8	1.00
				12 "	500	1	99.8	0.75
			Jan. 27	1 A.M.	500	1	99.8	0.75
				2 "	500	2	99.6	0.75
64	2	58		3 "	500	2	99.6	0.75
				4 "	500	2	99.6	0.75
				5 "	500	1	99.8	0.75
65	2	11		6 "	500	1	99.8	0.75
				7 "	600	2	99.7	0.63
				8 "	750	2	99.7	0.63
66	3	18		9 "	800	3	99.6	0.63
				10 "	800	2	99.8	0.63
				11 "	750	2	99.7	0.63
				12 M.	750	2	99.7	0.63
67	3	17		1 P.M.	700	2	99.7	0.63
				2 "	600	3	99.5	0.63
				3 "	550	2	99.6	0.63
68	4	15		4 "	550	2	99.6	0.63
				5 "	550	2	99.6	0.63
				6 "	550	3	99.4	0.63
				7 "	550	3	99.4	0.63
69	3	53		8 "	550	3	99.4	0.63
				9 "	550	3	99.4	0.63
				10 "	550	3	99.4	0.80
				11 "	500	10	98.0	1.95
				12 "	500	2	99.6	1.95
70	3	00	Jan. 28	1 A.M.	500	1	99.8	1.50
				2 "	500	1	99.8	1.50
				3 "	500	1	99.8	1.50
71	4	03		4 "	500	1	99.8	1.50
				5 "	500	1	99.8	1.50
				6 "	500	1	99.8	1.50
				7 "	500	1	99.8	1.30

TABLE 4.—(*Continued.*)

Number of run.	Lengths of run. Hours.	Minutes.	Date. Day.	Hour.	Turbidities, in parts per million. Raw water.	Rough-filtered water.	Percentage of removal.	Coagulant used, in grains per gallon.
72	4	04	Jan. 28.	8 A. M.	500	1	99.8	1.30
				9 "	500	1	99.8	1.30
				10 "	500	1	99.8	1.30
				11 "	500	1	99.8	1.22
73	4	56		12 M.	450	1	99.7	1.22
				1 P. M.	500	1	99.8	1.22
				2 "	500	1	99.8	1.22
				3 "	500	1	99.8	1.22
				4 "	500	1	99.8	1.22
				5 "	500	1	99.8	1.22
74	5	13		6 "	500	1	99.8	1.22
				7 "	500	1	99.8	1.30
				8 "	450	1	99.7	1.30
				9 "	450	1	99.7	1.30
				10 "	450	1	99.7	1.30
75	5	32		11 "	450	1	99.7	1.30
				12 "	450	1	99.7	1.30
			Jan. 29	1 A.M.	450	1	99.7	1.30
				2 "	450	1	99.7	1.30
				3 "	450	1	99.7	1.40
				4 "	450	1	99.7	1.40
76	5	19		5 "	450	1	99.7	1.40
				6 "	450	1	99.7	1.40
				7 "	400	1	99.7	1.40
				8 "	400	1	99.7	1.40
				9 "	300	1	99.7	1.40
77	6	50		10 "	300	0	100	1.30
				11 "	300	0	100	1.30
				12 M.	300	0	100	1.30
				1 P.M.	300	0	100	1.30
				2 "	275	0	100	1.30
				3 "	275	0	100	1.20
				4 "	275	0	100	1.20
				5 "	275	0	100	1.20
78	8	05		6 "	250	0	100	1.12
				7 "	250	0	100	1.12
				8 "	250	0	100	1.12
				9 "	250	0	100	1.12
				10 "	250	0	100	1.12
				11 "	250	0	100	1.12
				12 "	250	0	100	1.12
			Jan. 30	1 A.M.	250	0	100	1.12
79	10	59		2 "	250	0	100	1.12
				3 "	250	0	100	1.12
				4 "	250	0	100	1.12
				5 "	250	0	100	1.12
				6 "	250	0	100	1.12
				7 "	250	0	100	1.12
				8 "	250	0	100	1.12
				9 "	250	0	100	1.12
				10 "	250	0	100	1.12
				11 "	250	0	100	1.12
				12 M.	250	0	100	1.12
80	17	00		1 P.M.	200	0	100	1.12
				2 "	200	0	100	1.12
				3 "	200	0	100	0.99

TABLE 4.—(*Continued.*)

Number of run.	Lengths of run.		Date.		Turbidities, in parts per million.			Coagulant used, in grains per gallon.
	Hours.	Minutes.	Day.	Hour.	Raw water.	Rough-filtered water.	Percentage of removal.	
80	17	00	Jan. 30	4 P. M.	200	0	100	0.99
				5 "	200	0	100	0.99
				6 "	200	0	100	0.99
				7 "	200	0	100	0.99
				8 "	200	0	100	0.99
				9 "	200	0	100	0.99
				10 "	200	0	100	0.99
				11 "	200	0	100	0.99
				12 "	200	0	100	0.99
				1 A.M.	200	0	100	0.99
				2 "	200	0	100	0.99
				3 "	200	0	100	0.99
				4 "	150	0	100	0.99
				5 "	150	0	100	0.99
81	13	40		6 "	150	0	100	0.99
				7 "	150	0	100	0.99
				8 "	100	0	100	0.63
				9 "	100	0	100	0.63
				10 "	100	0	100	0.63
				11 "	100	0	100	0.63
				12 M.	75	0	100	0.55
				1 P.M.	75	0	100	0.55
				2 "	75	0	100	0.55

Four of the runs included in Table 4 were too short, and, with the experience since gained in handling the plant, particularly the coagulant, could have been extended by an hour or two without difficulty.

The complete records of the operation of Roughing Filter No. 1 by runs, from September 12th, 1908, to February 3d, 1909, are given in Table 5.

Analyses.—There is no laboratory for chemical and bacteriological work at the plant, but an arrangement has been made by which samples of the raw water, the rough-filtered water, the final-filtered water, and water secured from a faucet in the borough, are collected and examined by the chemist and bacteriologist of the Harrisburg Filter Plant once each week, and at such other times as desired. Two plates, for total numbers of bacteria, are prepared from each sample, and presumptive tests are made for the presence of *B. Coli* in the raw- and filtered-water samples, five 1-cu. cm. sowings usually being made of each sample; the tests for turbidity, free CO_2, and alkalinity are made at the plant by the superintendent, who is a skilled chemist.

TABLE 5.—

Run No.	From:	To:	Time in operation: Hours.	Time in operation: Minutes.	Loss of head: Initial.	Loss of head: Final.	Average rate of operation, in gallons daily.	Millions of gallons per acre per day.	Silica turbidity, in parts per million: Raw water.	Silica turbidity: Effluent.	Silica turbidity: Percentage removed.	Bacteria per cubic centimeter: Raw water.	Bacteria: Effluent.	Bacteria: Percentage removed.	Coagulant, in grains per gallon (average).
36	Jan. 10	Jan. 11	6	02	0.50	1.60	780 000	84.3	400	19.0	95	......	....	..	....
37	" 11	" 11	4	21	0.50	1.58	890 000	102.0	400	20.0	95	18 200	6 000	68	0
38	" 11	" 11	5	18	0.48	1.95	810 000	92.9	400	28.0	93	......	....	..	0
39	" 11	" 11	4	00	0.52	1.96	810 000	92.9	400	30.0	92	......	....	..	0
40	" 11	" 11	3	11	0.55	1.95	880 000	100.8	400	30.0	92	......	....	..	0.8
41	" 11	" 12	2	58	0.83	1.65	860 000	98.5	450	19.0	96	......	....	..	0.9
42	" 12	" 12	3	40	0.60	2.15	760 000	84.9	450	13.0	97	......	....	..	0.9
43	" 12	" 12	4	09	0.45	2.15	800 000	91.7	500	9.0	98	......	....	..	0.9
44	" 12	" 12	2	44	0.60	1.65	890 000	102.0	500	6.0	98	......	....	..	0.9
45	" 12	" 12	2	38	0.65	1.15	820 000	94.0	500	5.0	99	......	....	..	0.9
46	" 12	" 12	3	43	0.50	1.90	830 000	95.0	500	6.0	98	......	....	..	0.9
47	" 12	" 12	4	02	0.60	1.87	720 000	82.5	500	9.0	98	......	....	..	0.9
48	" 12	" 13	8	01	0.74	1.55	770 000	88.2	450	7.0	98	......	....	..	0.9
49	" 13	" 14	27	57	0.45	1.55	760 000	87.0	450	24.0	95	......	....	..	0.3
50	" 14	" 15	12	05	0.52	1.74	770 000	88.2	300	5.0	98	......	....	..	0.40
51	" 15	" 15	9	01	0.60	1.60	790 000	90.7	150	4.0	97	32 000	6 200	80	0.38
52	" 15	" 15	9	45	0.45	1.75	790 000	90.7	150	4.0	97	......	....	..	0.33
53	" 15	" 16	4	40	0.55	1.22	760 000	87.1	125	4.0	97	......	....	..	0.25
54	" 16	" 20	83	39	0.57	1.46	750 000	86.0	50	4.0	92	......	....	..	....
55	" 20	" 23	68	14	0.48	1.60	720 000	82.5	20	3.0	85	5 975	1 445	76	0.10
56	" 23	" 24	17	38	0.62	1.45	730 000	83.7	15	1.0	93	......	....	..	0.25
57	" 24	" 25	19	13	0.50	1.29	660 000	75.7	40	2.0	95	......	....	..	0.25
58	" 25	" 26	9	58	0.38	1.75	630 000	72.2	560	1.0	99	......	....	..	0.45
59	" 26	" 26	4	16	0.40	1.60	680 000	78.0	1 440	1.0	99	......	....	..	2.07
60	" 26	" 26	3	02	0.40	2.10	780 000	89.4	1 200	1.0	99	......	....	..	2.08
61	" 26	" 26	2	31	0.95	2.25	1 000 000	114.7	900	1.0	99	......	....	..	2.00
62	" 26	" 26	2	26	0.95	1.96	840 000	96.2	700	1.0	99	......	....	..	1.50
63	" 26	" 27	4	35	0.54	2.25	650 000	76.7	600	1.0	99	......	....	..	1.58
64	" 27	" 27	2	58	0.57	1.98	860 000	98.5	600	2.0	99	......	....	..	0.75
65	" 27	" 27	2	11	0.45	2.32	910 000	104.3	650	2.0	99	13 160	1 025	92	0.67
66	" 27	" 27	3	18	0.44	2.20	750 000	86.1	750	2.0	99	......	....	..	0.63
67	" 27	" 27	3	17	0.40	1.75	810 000	92.9	600	2.0	99	......	....	..	0.63
68	" 27	" 27	4	15	0.40	1.89	760 000	87.1	550	3.0	99	......	....	..	0.63
69	" 27	" 28	3	53	0.45	2.20	830 000	95.2	525	4.0	99	......	....	..	1.19

TABLE 5.—SUMMARY OF RESULTS OF OPERA

Run No.	From:	To:	TIME IN OPERATION: Hours.	Minutes.	LOSS OF HEAD: Initial.	Final.	Average rate of operation, in gallons daily.	Millions c gallons p acre per d	PARTS PER MILLION. Raw water.	Effluent.	Percentage removed.	CENTIMETER. Raw water.	Effluent.	Percentage removed.	Coagulant, grains per g lon (averag
1	Sept. 12	Oct. 5	570	43	0.35	1.76	710 000	81.4	6	....	...	......	....	..	....
2	Oct. 5	" 19	334	00	0.53	1.18	707 000	81.0	2	0.5	75	......	....	..	....
3	" 19	" 29	245	46	0.45	1.98	692 000	79.3	2	0.3	87	......	....	..	....
4	" 29	Nov. 3	125	08	0.45	1.70	700 000	80.3	7	0.0	100	......	....	..	....
5	Nov. 3	" 8	125	37	0.53	1.18	690 000	79.0	3	0.0	100	80	....	..	....
6	" 8	" 12	90	07	0.45	0.75	720 000	82.5	2	0.0	100	......	....	..	....
7	" 12	" 16	95	23	0.54	0.85	685 000	78.5	2	0.0	100	......	....	..	....
8	" 16	" 20	91	46	0.55	1.04	760 000	87.1	2	0.0	100	119	76	39	....
9	" 20	" 28	186	41	0.51	1.32	700 000	80.3	2	0.0	100	214	12	92	....
10	" 28	Dec. 4	161	00	0.45	1.68	770 000	88.2	1	0.0	100	......	....	..	....
11	Dec. 4	" 8	102	55	0.60	1.08	770 000	88.2	1	0.0	100	408	310	24	....
12	" 8	" 14	136	31	0.88	1.06	800 000	91.7	2	0.0	100	220	125	43	....
13	" 14	" 18	94	41	0.58	1.04	710 000	81.3	5	1.0	80	1 680	680	60	....
14	" 18	" 20	50	10	0.40	1.60	690 000	79.0	7	1.0	87	......	....	..	....
15	" 20	" 22	51	09	0.38	1.50	705 000	80.8	9	3.0	66	4 425	800	80	....
16	" 22	" 24	39	02	0.60	1.61	750 000	86.0	15	3.0	80	......	....	..	....
17	" 24	" 28	94	56	0.65	1.30	760 000	67.1	7	3.0	60	......	....	..	....
18	" 28	Jan. 1	87	17	0.56	0.92	750 000	86.0	4	1.0	75	......	....	..	....
19	Jan. 1	" 3	53	54	0.75	1.48	750 000	86.0	3	1.0	66	5 800	1 125	80	....
20	" 3	" 6	76	52	0.62	1.58	790 000	90.6	4	1.0	75	....	....	..	....
21	" 6	" 7	10	16	0.58	1.04	840 000	96.3	10	4.0	60	......	....	..	....
22	" 7	" 7	13	38	0.42	1.02	810 000	92.9	100	4.0	96	......	....	..	....
23	" 7	" 8	6	45	0.60	1.30	870 000	99.7	225	8.0	96	......	....	..	....
24	" 8	" 8	5	39	0.48	1.30	860 000	98.6	300	8.0	97	......	....	..	....
25	" 8	" 8	9	57	0.48	1.56	760 000	87.1	350	16.0	96	......	....	..	....
26	" 8	" 9	7	56	0.62	1.55	830 000	95.1	400	14.0	97	......	....	..	....
27	" 9	" 9	4	05	0.55	1.10	850 000	97.4	425	19.0	95	......	....	..	....
28	" 9	" 9	3	32	0.57	1.45	860 000	98.6	450	21.0	93	......	....	..	1.3
29	" 9	" 9	4	22	0.60	1.53	840 000	96.3	500	3.0	99	......	....	..	0.6
30	" 9	" 9	3	57	0.67	1.63	870 000	99.7	550	3.0	99	......	....	..	0.35
31	" 9	" 10	3	37	0.53	1.42	850 000	97.4	450	6.0	98	......	....	..	0.3
32	" 10	" 10	5	07	0.54	1.80	810 000	92.9	450	15.0	96	......	....	..	0.3
33	" 10	" 10	4	57	0.35	1.50	850 000	97.4	400	33.0	92	......	....	..	0.3
34	" 10	" 10	3	51	0.56	1.75	890 000	102.0	400	13.0	97	......	....	..	0.3
35	" 10	" 10	5	14	0.54	1.70	800 000	91.7	400	18.0	96	......	....	..	0.3

TABLE 5.—(*Continued.*)

Run No.	From:	To:	Time in operation: Hours.	Time in operation: Minutes.	Loss of head: Initial.	Loss of head: Final.	Average rate of operation, in gallons daily.	Millions of gallons per acre per day.	Silica turbidity, in parts per million: Raw water.	Silica turbidity: Effluent.	Silica turbidity: Percentage removed.	Bacteria per cubic centimeter: Raw water.	Bacteria: Effluent.	Bacteria: Percentage removed.	Coagulant, in grains per gallon (average).
70	Jan. 28	Jan. 28	3	00	0.60	2.17	760 000	87.1	500	1.0	99	......	....	..	1.50
71	" 28	" 28	4	03	0.40	2.20	760 000	87.1	500	1.0	99	......	....	..	1.45
72	" 28	" 28	4	04	0.45	2.20	780 000	89.5	500	1.0	99	......	....	..	1.28
73	" 28	" 28	4	56	0.60	2.16	780 000	89.6	500	1.0	99	......	....	..	1.22
74	" 28	" 28	6	13	0.50	1.82	760 000	86.1	450	1.0	99	......	....	..	1.28
75	" 28	" 29	3	32	0.40	2.11	720 000	82.6	450	1.0	99	......	....	..	1.33
76	" 29	" 29	5	19	0.57	1.99	740 000	84.9	300	0.0	100	......	....	..	1.44
77	" 29	" 29	6	50	0.57	1.99	700 000	80.3	250	0.0	100	......	....	..	1.28
78	" 29	" 30	8	05	0.40	1.88	710 000	81.4	250	0.0	100	......	....	..	1.12
79	" 30	" 30	10	59	0.44	1.95	580 000	66.6	250	0.0	100	......	....	..	1.12
80	" 30	" 31	17	00	0.44	1.86	560 000	64.2	250	0.0	100	......	....	..	1.00
81	" 31	" 31	13	40	0.65	1.43	740 000	84.9	100	0.0	100	......	....	..	0.65
82	" 31	Feb. 1	10	38	0.56	1.40	650 000	74.5	75	0.0	100	......	....	..	0.55
83	Feb. 1	" 2	23	13	0.60	1.50	730 000	83.7	60	0.0	100	......	....	..	0.50
84	" 2	" 2	12	47	0.60	1.86	810 000	93.0	50	0.0	100	......	....	..	0.60
85	" 2	" 3	10	11	0.60	1.46	790 000	90.7	30	2.0	98	......	....	..	....

The area of the filter = 0.008719 acre.

Air Wash.—The roughing filters, when clogged, or when not yielding a satisfactory effluent, are cleaned by washing with air and water, first shutting off the raw-water supply and then, if pushed for time, opening the sewer gate and wasting the water upon the surface of the filter down to the level of the wash-water troughs. The filter, in the meantime, being in operation, is allowed to run until the surface of the water on it has dropped about 6 in. below the edges of the wash-water troughs; the effluent gate is then closed, and compressed air is discharged into the underdrains from the air receiver. The compressed air is stored in the receiver at a pressure of approximately 100 lb. per sq. in. at the beginning of the wash, and is discharged through a reducing valve set at about 10 lb. on the filter side of the valve; this, however, does not represent the pressure at which the air is applied during the wash, as the 10 lb. is largely used up in friction through the small air pipes leading to the filters. The air issues into the filter through the orifices in the bottom of the 2-in. galvanized-iron underdrain pipes 1 in. above the floor of the filter. The bottoms of the pipes lying all in the same plane, the air issues from the orifices only as it is forced out by the pressure in the delivery pipe, its tendency to issue by its own buoyancy being overcome by placing the orifices in the bottoms of the pipes; within limits, therefore, it is possible to deliver to the filter any quantity of air desired, and to have it issue through all the orifices in the underdrain pipes with practical uniformity. The application of the air is continued until the contents of the receiver, approximating 1 500 cu. ft. of free air, is discharged, which takes from 4 to 5 min., as the reducing valve is now set, and this corresponds to approximately 1 cu. ft. of free air per square foot of filter surface per minute. Apparently, this is sufficient, for, as far as can be ascertained, there has been no tendency for suspended matters to accumulate in the filter permanently. The objection to the use of a large quantity of air, or to very heavy air washing, is the likelihood of the disturbance of the gravel underdrains to be followed by the loss of some of the filtering material; and the tendency to aid in producing vertical stratification in the filter, in connection with the water-wash, allowing some portions to clog up completely, and increasing the velocity of filtration through the more porous parts to such an extent as to render the filter ineffective. In order to guard against this tendency, the superintendent, from time to time, stirs up by hand the

filtering materials in the roughing filters, using a rake while the wash-water is being applied; this dissipates effectively any tendency of the materials to collect in vertical strata, and maintains the porosity and efficiency of the filter.

Water-Wash.—After the air is turned off the filters are washed with filtered water from the street mains. The water is applied through the underdrains, and the dirty water overflows into the wash-water troughs and passes thence to the river through the sewer. The wash-water is ordinarily applied at a rate equivalent to about three and one-half times the rate of filtration, or between 8 and 9 vertical inches in the filter per minute, the duration of the water-wash being from 5 to 6 min., and the quantity of water used per wash about 10 000 gal. In addition to that used for washing, about 5 000 gal. are wasted from the surface of the filter at each wash when the turbidity is high and the filters have to be washed frequently. It cannot, as yet, be told with accuracy just what percentage of wash-water will be required during the year, but a prediction of the quantity can be made from data secured at the Harrisburg Testing Station, and at the Harrisburg Filter Plant. The number of washes required will depend on the turbidity of the raw water, as this causes the clogging of the filter and necessitates the use of a coagulant.

TABLE 6.—EFFECT OF TURBIDITY OF RAW WATER ON LENGTHS OF RUNS OF ROUGHING FILTERS AT STEELTON.

Turbidity of applied water, in parts per million.		Number of days per year when such turbidities may be expected to prevail.	Average lengths of runs.
Range. (1)	Average. (2)	(3)	(4)
0– 50	25	160	6 days.
51– 75	62	65	21 hours.
76– 100	88	35	17 "
101– 150	125	29	12 "
151– 200	175	23	10 "
201– 250	225	18	9 "
251– 500	375	25	7 "
501– 800	650	7	5 "
801–1 200	1 000	5	4 "
1 200+	1 400	3	3 "

Lengths of Runs.—The data thus far secured from the Steelton plant, in addition to information from the Harrisburg Testing Station, indicate that the lengths of runs from the roughing filters, when operat-

ing at a rate of from 75 000 000 to 125 000 000 gal. per acre per day, would be about as shown in Table 6. Column 1 indicates the range of turbidity of the raw water, Column 2 the average turbidity, Column 3 the approximate number of days per year when such turbidities may be expected to prevail, and Column 4 the lengths of runs of the roughing filters.

Using the data in Table 6, 428 washes per year per filter will be required, calling for a total of about 6 700 000 gal. of wash- and waste-water, assuming that the water on the surface of the roughing filters is wasted at each wash. As it takes about 15 min. to wash a filter, the necessary lost time for the 428 washes would be 4½ days per year, and the output of each filter for the 360.5 days of operation, at its full rated capacity, 1 500 000 gal. per day, would be 540 500 000 gal.; the wash- and waste-water, on this basis, would represent 1.2% of the net output of the filter for the year.

The longest run yet experienced was about 24 days, and the shortest 2 hours 11 min. It is believed that with more experience the shortest runs need not be less than about 4 hours.

TABLE 7.—AVERAGE DOSE OF COAGULANT.

Turbidity of applied water, in parts per million.		Number of days per year when such turbidities may be expected to prevail.	Average dose of aluminum sulphate, in grains per gallon.	Average dose of lime, in grains per gallon.
Range. (1)	Average. (2)	(3)	(4)	(5)
0– 50	25	160	0.0	0
51– 75	62	65	0.4	0
76– 100	88	35	0.5	0
101– 150	125	29	0.6	0
151– 200	175	23	0.7	0
201– 250	225	13	0.8	0
251– 500	375	25	1.0	0.25
501– 800	650	7	1.4	0.40
801–1 200	1 000	5	1.7	0.60
1 200+	1 400	3	2.1	0.75

Average Dose of Coagulant.—From the data thus far secured, it would appear that the average quantities of coagulant necessary in the operation of the plant would be about as shown in Table 7, from which a calculation indicates that the average dose required through a series of years would be equivalent to 0.37 gr. per gal., or 53 lb. per million gallons of water treated, which, at $20 per ton, gives the average cost for coagulant as 53 cents per million gallons. For the

first year the quantity required will fall far short of this figure, the average dose from September 16th, 1908, to April 18th, 1909, having been but 0.22 gr. per gal.

Effect of Turbidity on Initial Loss of Head.—The initial loss of head, at the commencement of operation of a roughing filter, is not affected either by the turbidity of the raw water or the quantity of aluminum sulphate used, the effects of these two factors being evident only in the rate at which the loss of head increases, and consequently in the lengths of the runs.

Effect of Rate on Quantity Filtered.—The rate of filtration affects only slightly the total quantity of water that may be filtered between washings of the roughing filters; whatever slight effect there may be apparently indicates that somewhat larger quantities can be filtered between washings at high rates than at low rates, but, of course, at the expense of somewhat more frequent washings.

Operation of Slow Filters.

The slow filters are operated on the continuous plan, the rough-filtered water being controlled so as to stand about 2 ft. deep on the surface of the slow filters.

The method of regulating the rate of filtration need not be again described, it being sufficient to state that the yield of the slow filters is responsive to the draft of the municipal high-pressure pumps, up to the limit of the discharging capacity of the regulating devices on the filters. As filtration proceeds, the slow filters gradually clog up, and the loss of head increases; provision is made to allow for a total loss of head of 7 ft. in the slow filters, which is the full depth of the filtering materials, and the superincumbent water.

Daily Records.—The slow filters were put in operation on September 16th, 1908. The daily records of the operation of Filter No. 1 are given in Table 8, from which it will be seen that the accumulation of the loss of head proceeded with comparative slowness during September, October, and November, while during December the occasional increase in turbidity of the raw water began to have its effect on clogging, bringing the total loss of head up to about 2 ft. on the last day of December. In January, 1909, during which there were two periods of bad water, the loss of head increased to about 6 ft., a gain of 4 ft., during the month, and it became necessary to start scraping.

On the morning of January 30th, therefore, the supply to Filter No. 1 was shut off, the water was drained down to the surface of the filter, and filtration was continued for a short time to allow the water to fall a sufficient distance below the sand surface.

TABLE 8.—RECORD OF OPERATION OF SLOW FILTER NO. 1, SEPTEMBER 16TH, 1908, TO FEBRUARY 1ST, 1909.

Date.	Time in service: Days.	Hours.	Loss of head, in feet.	Rate of Operation: Gallons daily.	Millions of gallons per acre per day.
(1)	(2)		(3)	(4)	(5)
Sept. 16	..	..	0.38	680 000	4.7
" 17	1	..	0.36	650 000	4.5
Oct. 1	15	..	0.33	610 000	4.2
" 4	18	..	0.35	600 000	4.1
" 9	23	..	0.45	600 000	4.1
" 10	24	..	0.30	520 000	3.6
" 14	28	..	0.49	510 000	3.5
" 17	31	..	0.35	500 000	3.4
" 23	37	..	0.40	530 000	3.7
" 28	42	..	0.35	630 000	4.3
" 31	45	..	0.30	520 000	3.6
Nov. 4	49	..	0.40	580 000	4.0
" 14	59	..	0.63	500 000	3.4
" 25	70	..	0.61	500 000	3.4
" 30	75	..	0.75	500 000	3.4
Dec. 1	76	..	0.75	500 000	3.4
" 5	80	..	0.85	500 000	3.4
" 8	83	..	1.70	500 000	3.4
" 11	86	..	1.50	680 000	4.7
" 17	92	..	1.20	500 000	3.4
" 23	98	..	1.60	500 000	3.4
" 26	101	..	1.33	500 000	3.4
" 27	102	..	1.95	500 000	3.4
" 31	106	..	2.07	500 000	3.4
Jan. 1	107	..	2.09	500 000	3.4
" 3	109	..	2.20	500 000	3.4
" 4	110	..	2.35	500 000	3.4
" 5	111	..	2.42	500 000	3.4
" 9	115	..	2.92	500 000	3.4
" 12	118		3.70	500 000	3.4
" 15	121	..	3.74	500 000	3.4
" 18	124	..	4.23	500 000	3.4
" 22	128	..	4.12	500 000	3.4
" 25	131	..	5.01	500 000	3.4
" 27	133	..	5.35	500 000	3.4
" 28	134	..	5.99	500 000	3.4
" 29	135	..	5.75	500 000	3.4
" 30	135	7	6.01	500 000	3.4

Filter put in service September 16th, 1908.
Filter scraped January 30th, 1909.
Sand removed, washed, and stored, 18 cu. yd. = 124 cu. yd. per acre.
Quantity filtered during run = 71 000 000 gal.
Millions of gallons per acre filtered between scrapings = 491.
Average rate of filtration = 3 623 000 gal. per acre daily.
Net area of sand surface = 0.1446 acre.
Wasted from surface of filter for scraping ....104 500 gal.
Water drained out, and water used for refilling from below...156 800

261 300 = 0.36% of filtrate.

Scraping.—Filter No. 1 was scraped by the superintendent of the plant and a force of five men, the actual time occupied in piling up

the scrapings ready for transportation to the washer being 3 hours, or at the rate of about 7 sq. ft. of filter scraped per man per minute. The scraping on this filter was rather deep, averaging nearly an inch, and being less than ¾ in. in very few places. A portion of the extra scraping was made necessary by the accidental dropping of one of the manhole covers into the filter early in January. This caused a great disturbance of the sand, over an area of perhaps 100 sq. ft., as the cover turned when it struck the water and penetrated the sand bed on its edge, the lower corner having reached almost to the gravel under-drains. The cover was taken out, and all the discolored sand which had been driven down into the bed from the *schmützdecke* was dug out and sent to the washer.

Sand Transportation and Washing.—The ejector and washing plant worked satisfactorily as to the handling of the sand, but, as it had not been in use before, the men did not attain a high degree of efficiency in its operation. It is believed that greater familiarity with its use, and the proper regulation of the relative force of the different jets, will permit of handling the sand much more rapidly and efficiently than was done. The total quantity of sand removed from Filter No. 1 was about 18 cu. yd., or 124 cu. yd. per acre of filter surface, to transport which to the sand washer, wash it, and return it to the sand troughs on top of the filters occupied about 8 hours, one man attending to the sand washer, one to the hose returning the sand to the sand troughs, one raking the scraped surface of the filter, and an average of three shoveling the dirty sand to the portable ejector.

After the sand for one filter had all been washed, the portable ejector was taken apart and an irregularly-shaped stone, which had carelessly been left in one of the water mains, was found wedged in the nozzle. This had caused the deflection of the jet of water so that the throat on the discharge side had been cut deeply. After the throat had been replaced with a new one, the original capacity of the ejector was restored, and the scraping and transporting of sand to the washer from the other filters proceeded with more expedition.

Ejector Nozzles.—The nozzle in the portable ejector throws a ⅝-in. jet of water into a throat with a 1½-in opening reduced to 1 in. in diameter 1½ in. from the front of the throat and increasing to 1⅜ in. in diameter at the back end of the throat 7 in. from the face; the nozzle and throat stand 1½ in. apart. The nozzle reduces from 2 in. in

diameter to the $\frac{5}{8}$-in. jet in a length of about 6 in. The nozzles and throats are of chilled cast iron.

The nozzles for the sand washer have a $\frac{19}{32}$-in. jet, and the throats reduce from $1\frac{1}{2}$ in. to $1\frac{1}{8}$ in. in diameter in $1\frac{1}{2}$ in., increasing to $1\frac{3}{4}$ in. in $5\frac{1}{2}$ in. The portable ejector and the washing hoppers were supplied by the Norwood Engineering Company, from designs by Allen Hazen, M. Am. Soc. C. E., originally worked out for the filter plant at Washington, D. C., and containing recent improvements suggested by Mr. Hazen. The washing plant consists of only two hoppers, and practically all the washing is done in the first one, the sand as it is thrown to the second hopper from the first being sufficiently clean to be used in the filter. The wash-water overflows the second hopper with very little turbidity.

The lift from the portable ejector to the top of the pipe discharging into the washing hopper is about 15 ft.; from the second washing hopper to the sand troughs there is a drop of about 6 ft., so that comparatively little pressure is required to transport the sand from the sand washer back to the sand bins.

The washing hoppers are provided with auxiliary jets at the bottom to compensate for the quantity of dirty water actually picked up by the jet and forced through to the succeeding hopper, the auxiliary jet also serving the purpose of stirring up the sand at the bottom of the hopper so as to facilitate its transportation by the water jet. The dirty water overflowing the washing hoppers passes through a reinforced concrete box in order to catch such sand as may escape with the wash-water; the dirty water escapes from this box to the sewer by an overflow.

The water which transports the washed sand to the sand troughs overflows a weir at one end of each sand box and escapes to the sewer.

Refilling after Scraping.—After the dirty sand is all thrown out of the filter and the surface of the clean sand has been raked over to remove footprints and give a smooth even surface, filtered water is admitted through the underdrains until the surface of the filter sand is covered about 2 in. in depth; the raw water is then admitted, gently at first, and the filter is refilled to its proper operating depth with the rough-filtered water.

Resumption of Filtration.—In starting this filter in operation after scraping, the effluent control valve was regulated so that the filter would

deliver, according to its rate-gauge, 800 000 gal. a day, it being necessary to choke down the discharge of the clean filter to a proper rate because the two other filters were very much clogged up and could not yield their proportional part of the water without a loss of head of 5 or 6 ft.; with such a loss of head the clean filter would at once start off with its maximum allowable rate, which was deemed inadvisable, the filter being so new, and having been started in operation so late in the season.

Lengths of Runs.—Filter No. 2 was scraped on February 2d and was put back in service on February 3d, and Filter No. 3 on February 4th, 1909. The lengths of runs of these three filters, therefore, were 135.5, 137.5 and 140.5 days, respectively. Filter No. 1 delivered during its run 71 000 000 gal. at an average rate of 3 623 000 gal. per acre daily, the total yield corresponding to 491 000 000 gal. per acre between scrapings. The figures for the other two filters were a trifle larger.

The total quantity of water wasted from the surface of the filter prior to scraping, and the quantity used for refilling the filter from below, before starting in operation again, corresponded to 0.14 of 1% of the quantity of water filtered.

The three slow filters have now (May 10th, 1909) been in service for 14 weeks since the last (and only) scraping, and the loss of head is but 0.7 ft.

Efficiency of the Plant.

The efficiency of the entire plant, in the removal of turbidity and bacteria, is exhibited in the daily records given in Table 9, which date from November 1st, 1908, for the reason that no bacterial analyses were made prior to November 5th.

The efficiency in the removal of turbidity has been 100 per cent. During November and December, when the turbidity of the raw water was low and the bacteria were not numerous, the effluent water was satisfactory. The same is true during January, with the exception of the second week when, as has already been explained, the superintendent was deceived by the deterioration of his silica-turbidity standards, and the quantity of coagulant was inadequate to produce a satisfactory effluent. The results subsequent to that date are good. The samples collected on the afternoon of February 5th, when Filter No. 3 was being scraped, represent the bacterial contents of the effluents of Filters Nos. 1 and 2, which had been scraped, No. 2 within two days

TABLE 9.—Daily Efficiency of Plant in Removal of Turbidity and Bacteria.

Date.	Average turbidities, in parts per million: Raw water.	Rough-filtered water.	Filtered water.	Percentage of removal.	Bacteria, per cubic centimeter: Raw water.	Rough-filtered water.	Filtered water.	Percentage of removal.	Average dose of coagulant, in grains per gallon.	Alkalinity of raw water, in parts per million.
1908.										
Nov. 1...	5	0	0	100	......	......	......	......	......	......
2...	4	0	0	100	......	......	......	......	......	......
3...	3	0	0	100	......	......	......	......	......	......
4...	2	0	0	100	......	......	......	......	......	......
5...	3	0	0	100	80	......	3	96	......	......
6...	3	0	0	100	......	......	......	......	......	......
7...	3	0	0	100	......	......	......	......	......	......
8...	3	0	0	100	......	......	......	......	......	......
9...	2	0	0	100	......	......	......	......	......	......
10...	2	0	0	100	......	......	......	......	......	......
11...	2	0	0	100	......	......	......	......	......	......
12...	2	0	0	100	......	......	......	......	......	......
13...	2	0	0	100	......	......	......	......	......	......
14...	2	0	0	100	......	......	......	......	......	......
15...	1	0	0	100	......	......	......	......	......	......
16...	2	0	0	100	......	......	......	......	......	......
17...	3	1	0	100	......	......	......	......	......	......
18...	3	1	0	100	......	......	......	......	......	......
19...	2	0	0	100	......	......	......	......	......	......
20...	2	0	0	100	119	76	6	95	......	......
21...	2	0	0	100	......	......	......	......	......	......
22...	2	0	0	100	......	......	......	......	......	......
23...	2	0	0	100	......	......	......	......	......	......
24...	2	0	0	100	......	......	......	......	......	......
25...	2	0	0	100	......	......	......	......	......	......
26...	1	0	0	100	......	......	......	......	......	......
27...	1	0	0	100	214	12	3	99	......	......
28...	1	0	0	100	......	......	......	......	......	......
29...	1	0	0	100	......	......	......	......	......	......
30...	1	0	0	100	......	......	......	......	......	......
Dec. 1...	1	0	0	100	......	......	......	......	......	......
2...	1	0	0	100	......	......	......	......	......	......
3...	1	0	0	100	......	......	......	......	......	......
4...	1	0	0	100	......	......	......	......	......	......
5...	1	0	0	100	......	......	......	......	......	......
6...	1	0	0	100	408	310	52	87.2	......	......
7...	1	0	0	100	......	......	......	......	......	......
8...	1	0	0	100	......	......	......	......	......	......
9...	1	0	0	100	......	......	......	......	......	......
10...	1	0	0	100	......	......	......	......	......	......
11...	1	1	0	100	......	......	......	......	......	......
12...	2	1	0	100	220	125	8	96.4	......	......
13...	3	1	0	100	......	......	......	......	......	......
14...	4	1	0	100	......	......	......	......	......	......
15...	4	1	0	100	......	......	......	......	......	......
16...	4	1	0	100	......	......	......	......	......	......
17...	4	0	0	100	1 680	680	71	95.9	......	......
18...	7	1	0	100	......	......	......	......	......	......
19...	8	1	0	100	......	......	......	......	......	......
20...	4	1	0	100	......	......	......	......	......	......
21...	5	1	0	100	4 425	800	58	98.7	......	......
22...	15	4	0	100	......	......	......	......	......	......
23...	18	2	0	100	......	......	......	......	......	......

TABLE 9.—(*Continued.*)

Date.	Average turbidities, in parts per million:				Bacteria, per cubic centimeter:				Average dose of coagulant, in grains per gallon.	Alkalinity of raw water, in parts per million.
	Raw water.	Rough-filtered water.	Filtered water.	Percentage of removal.	Raw water.	Rough-filtered water.	Filtered water.	Percentage of removal.		
1908.										
Dec. 24...	10	3	0	100	......	......	......	......	......	......
25...	10	3	0	100	......	......	......	......	......	......
26...	6	2	0	100	......	......	......	......	......	......
27...	5	1	0	100	......	......	......	......	......	......
28...	4	1	0	100	......	......	......	......	......	......
29...	3	1	0	100	......	......	......	......	......	......
30...	3	1	0	100	......	......	......	......	......	......
31...	2	1	0	100	......	......	......	......	......	......
1909.										
Jan. 1...	4	1	0	100	5 800	1 125	100	98.3	......	......
2...	2	1	0	100	......	......	......	......	......	......
3...	3	1	0	100	......	......	......	......	......	......
4...	3	1	0	100	......	......	......	......	......	......
5...	3	1	0	100	......	......	......	......	......	......
6...	7	2	0	100	......	......	......	......	......	......
7...	120	4	0	100	......	......	......	......	......	......
8...	250	10	0	100	......	......	......	......	......	......
9...	450	14	0	100	......	......	......	......	0.5	......
10...	400	20	0	100	......	......	......	......	0.15	......
11...	425	20	0	100	18 200	6 000	1 105	93.9	0.30	......
12...	450	7	0	100	......	......	......	......	0.90	......
13...	250	12	0	100	......	......	......	......	0.10	......
14...	180	12	0	100	......	......	......	......	0.20	......
15...	125	4	0	100	32 000	6 200	320	99.0	0.35	......
16...	75	4	0	100	......	......	......	......	0.30	......
17...	60	5	0	100	......	......	......	......	0.10	0
18...	30	4	0	100	......	......	......	......	......	......
19...	25	4	0	100	......	......	......	......	......	......
20...	20	4	0	100	......	......	......	......	......	......
21...	35	4	0	100	5 975	1 445	115	98.1	......	......
22...	15	2	0	100	......	......	......	......	0.25	......
23...	10	1	0	100	......	......	......	......	0.25	......
24...	20	1	0	100	......	......	......	......	0.25	18
25...	50	2	0	100	......	......	......	......	0.25	23
26...	770	1	0	100	......	......	......	......	1.38	26
27...	600	2	0	100	13 160	1 025	11	99.9	0.78	23
28...	490	1	0	100	......	......	......	......	1.32	16
29...	325	0	0	100	......	......	......	......	1.35	22
30...	225	0	0	100	......	......	......	......	1.00	20
31...	100	0	0	100	......	......	......	......	0.65	22
Feb. 1...	75	0	0	100	......	......	......	......	0.55	16
2...	60	0	0	100	......	......	......	......	0.50	18
3...	20	3	1	95	......	......	......	......	......	14
4...	20	2	0	100	......	......	......	......	0.25	......
5*..	15	0	0	100	3 025	295	188	94	0.25	......
6...	70	0	0	100	......	......	......	......	0.25	14
7...	45	0	0	100	......	......	......	......	0.40	17
8...	190	2	0	100	......	......	......	......	0.60	14
9...	170	0	0	100	......	......	......	......	0.60	12
10...	215	0	0	100	......	......	......	......	0.60	13
11...	170	0	0	100	......	......	......	......	0.60	12

* Filter No. 3 out of service for scraping; Filter No. 1 was scraped on January 30th, and No. 2 on February 3d.

TABLE 9.—(*Continued.*)

Date.	Average turbidities, in parts per million: Raw water.	Rough-filtered water.	Filtered water.	Percentage of removal.	Bacteria, per cubic centimeter: Raw water.	Rough-filtered water.	Filtered water.	Percentage of removal.	Average dose of coagulant, in grains per gallon.	Alkalinity of raw water, in parts per million.	Free CO_2 in raw water, in parts per million.	Average dose of lime used, in grains per gallon.
1909.												
Feb. 12..	270	0	0	100	16 000	500	47	99.7	0.65	13	....	0
13..	160	0	0	100	....	....	..	....	0.65	15	....	0
14..	80	0	0	100	....	....	..	....	0.35	16	....	0
15..	50	0	0	100	....	....	..	....	0.33	14	....	0
16..	120	0	0	100	....	....	..	....	0.50	13	....	0
17..	200	0	0	100	....	....	..	....	0.70	10	....	0
18..	310	8	0	100	....	....	..	....	0.80	6	3	0.42
19..	190	0	0	100	4 500	115	25	99.5	1.00	6.5	3.5	0.42
20..	125	2	0	100	....	....	..	....	1.20	7.5	3	0.30
21..	300	0	0	100	....	....	..	....	0.90	9	4	0.30
22..	390	0	0	100	....	....	..	....	0.80	9	....	0
23..	466	2	0	100	....	....	..	....	1.10	11	....	0
24..	380	0	0	100	....	....	..	....	1.00	11.5	....	0
25..	275	0	0	100	....	....	..	....	0.85	11.5	....	0
26..	310	0	0	100	....	....	..	....	0.80	10	....	0
27..	310	0	0	100	6 850	70	10	99.8	0.80	11	....	0
28..	260	0	0	100	....	....	..	....	0.80	11	....	0
Mch. 1..	150	0	0	100	....	....	..	....	0.65	11	....	0
2..	120	0	0	100	....	....	..	....	0.65	8	....	0
3..	100	0	0	100	....	....	..	....	0.50	7	....	0
4..	65	0	0	100	....	....	..	....	0.40	6	....	0
5..	52	1	0	100	....	....	..	....	0.40	6	....	0
6..	47	1	0	100	3 425	750	61	98.2	0.00	8	....	0
7..	45	0	0	100	....	....	..	....	0.00	10	....	0
8..	60	0	0	100	....	....	..	....	0.35	11	....	0
9..	60	0	0	100	....	....	..	....	0.35	12	....	0
10..	50	0	0	100	....	....	..	....	0.35	12	....	0
11..	50	0	0	100	....	....	..	....	0.35	11	....	0
12..	90	0	0	100	....	....	..	....	0.35	11	....	0
13..	120	0	0	100	2 325	85	10	99.6	0.40	14	....	0
14..	115	0	0	100	....	....	..	....	0.40	16	....	0
15..	100	0	0	100	....	....	..	....	0.40	14	....	0
16..	75	0	0	100	....	....	..	....	0.30	14	....	0
17..	47	0	0	100	....	....	..	....	0.30	12	....	0
18..	42	0	0	100	....	....	..	....	0.30	14	....	0
19..	45	0	0	100	....	....	..	....	0.30	14	....	0
20..	40	0	0	100	....	....	..	....	0.30	14	....	0
21..	30	0	0	100	....	....	..	....	0.25	14	....	0
22..	25	0	0	100	....	....	..	....	0.25	16	....	0
23..	22	0	0	100	1 000	55	5	99.5	0.25	16	....	0
24..	20	0	0	100	....	....	..	....	0.00	15	....	0
25..	20	0	0	100	....	....	..	....	0.25	15	....	0
26..	25	0	0	100	....	....	..	....	0.25	14	....	0
27..	110	0	0	100	*	220	17	....	0.40	14	....	0
28..	140	0	0	100	....	....	..	....	0.55	14	....	0
29..	120	0	0	100	....	....	..	....	0.57	12	....	0
30..	150	0	0	100	....	....	..	....	0.62	14	....	0
31..	135	0	0	100	....	....	..	....	0.57	14	....	0
Apr. 1..	100	1	0	100	....	....	..	....	0.47	12	....	0
2..	85	0	0	100	....	....	..	....	0.45	14	....	0
3..	72	1	0	100	2 950	56	16	99.5	0.40	16	....	0
4..	60	1	0	100	....	....	..	....	0.32	16	....	0
5..	50	1	0	100	....	....	..	....	0.35	17	....	0
6..	50	1	0	100	....	....	..	....	0.40	19	....	0
7..	50	1	0	100	....	....	..	....	0.40	19	....	0
8..	55	0	0	100	....	....	..	....	0.45	18	....	0
9..	100	0	0	100	....	....	..	....	0.52	15	....	0
10..	95	0	0	100	....	....	..	....	0.48	14	....	0
11..	80	0	0	100	....	....	..	....	0.45	16	....	0
12..	95	0	0	100	....	....	..	....	0.50	15	....	0
13..	80	1	0	100	1 500	38	4	99.7	0.45	14	....	0
14..	42	1	0	100	....	....	..	....	0.35	14	....	0
15..	140	1	0	100	....	....	..	....	0.49	13	....	0
16..	345	1	0	100	....	....	..	....	0.80	12	....	0
17..	350	20	0	100	8 600	475	2	99.9	1.25	12	3	0.25
18..	340	0	0	100	....	....	..	....	1.00	11	2	0.25

* Raw water sample not taken.

and No. 1 within 5 days of the date of taking the sample. The individual samples of the effluents of Nos. 1 and 2 showed the following counts:

Filter No. 1, put in service, January 31st.

Sample No. 1..... 185 (collected February 5th)
Sample No. 2..... 170 (" " ")

Average...... 176

Filter No. 2, put in service February 3d.

Sample No. 1..... 200 (collected February 5th)
Sample No. 2..... 185 (" " ")

Average...... 198

A slight improvement shows in the effluent of the older filter.

The efficiency in the removal of *B. Coli* is shown in Table 10.

TABLE 10.—PRESUMPTIVE TESTS FOR PRESENCE OF *B. Coli* IN THE RAW WATER, FILTERED WATER AT THE FILTER PLANT, AND TAP WATER IN STEELTON, PA.

Date.	Raw Water.		Filtered Water.		Tap Water.	
	Number of 1-cu. cm. sowings.	Positive indications.	Number of 1-cu. cm. sowings.	Positive indications.	Number of 1-cu. cm. sowings.	Positive indications.
Nov. 20, 1908.	5	3	5	0	5	0
" 27	5	3	5	0	5	0
Dec. 6	5	3	5	0	5	0
" 12	5	1	5	0	..	..
" 17	5	1	5	0	5	0
" 21	4	1	4	1	4	0
Jan. 1, 1909.	5	1	5	0	5	0
" 11	5	5	5	4	5	5
" 15	5	3	5	1	5	0
" 21	5	4	5	0	5	1
" 27	5	5	5	0	5	0
Feb. 5	4	3	4	0	4	0
" 12	4	4	4	0	4	0
" 19	3	1	3	0	3	0
" 27	5	5	5	1	5	0
Mch. 6	5	2	5	0	5	0
" 13	5	3	5	0	5	0
" 23	5	4	5	0	5	0
" 27	..	..	5	0	5	0
Apr. 3	5	5	5	0	5	0
" 13	4	3	4	0	4	0
" 17	4	4	4	0	4	0

The presence of *B. Coli* in the filtered water on December 21st, January 11th, and January 15th was in part due to lack of, or insufficient use of, coagulant in the preliminary process. The dropping of

a manhole cover into Filter No. 3 on January 1st, however, may have contributed to the deterioration of the effluent during the early part of that month.

Thus far, no chemical analyses have been made of the applied water and final filtrate at the Steelton plant, and no data, therefore, have been secured on the degree of nitrification accomplished, or on the other usual changes expected. It is evident that between periods of turbid water, when no coagulant is being used, the slow sand filters will be penetrated deeply by such suspended matters as may pass through the roughing filters, among which would be bacteria, and in this respect the work required of these filters will differ from that performed by the ordinary slow sand filter. During the past few months no visible suspended matters have been left in the rough-filtered water.

In nearly all plants using aluminum sulphate as a coagulant, trouble, either continuously or intermittently, has been experienced with discoloration of the water, generally only the hot water, by iron rust. This trouble has been more or less serious at Harrisburg, Pa., Watertown, N. Y., Charleston, S. C., Hackensack, N. J., and various other places. Thus far, there has been no trouble of this sort at Steelton, although at times as much as 2 gr. of aluminum sulphate has been used per gallon of water filtered.

Cost of Operation.—The plant has not yet been in operation sufficiently long to obtain accurate data, but an approximation for an average year would indicate an expense, per million gallons, when filtering 3 000 000 gal. of water daily, about as follows:

Cost of Purification of Steelton Water per Million Gallons, on a Basis of Filtering 3 000 000 Gal. per Day.

Operation of Roughing Filters.		
Labor	$1.55	
Superintendence	0.42	
Supplies and analyses of water	0.30	
Coagulant	0.53	
Power	0.08	
Wash-water	0.13	
Light	0.05	
Coal	0.10	
	——	$3.16

Operation of Slow Filters.

Scraping, 5 times per year	$0.60	
Transporting and washing sand	0.06	
Re-sanding filters	0.25	
Superintendence	0.42	
	——	$1.33
Total		$4.49

Interest and sinking fund charges are not included.

Acknowledgments.—The principal credit for the existence of the Steelton filter plant is due to J. V. W. Reynders, M. Am. Soc. C. E., President of Councils of Steelton, Chairman of the Filtration Committee of Councils and Vice-President of the Pennsylvania Steel Company, who, by arranging a well-conducted campaign of education and devoting much thought and time to the cause, prepared the way to enable Councils to see the necessity of making provisions for a purer water supply.

On its completion, the plant was turned over for operation to the Board of Water Commissioners, Mr. George H. Roberts, President, under the general direction of the Superintendent of the Water-Works, Mr. O. P. Baskin. The operation of the filters is in charge of Mr. M. B. Litch, as Filter Superintendent, the writer, acting in an advisory capacity, as required.

The works were built by contract under the supervision of the writer's engineering force, Mr. Paul Hooker being Principal Assistant during the designing of the works, and Resident Engineer during their construction; to his faithfulness the plant bears permanent witness.

TABLE 2.—Tests of a 28-inch R. H. Wellman-Seaver-Morgan Company Turbine Wheel, No. 1796.

Date, February 25th, 1909.

Wheel supported by ball-bearing step. Swing-gate. Conical draft-tube.

Number of experiment.	Proportional Part of: Percentage of full opening of speed-gate.	Proportional Part of: Percentage of full discharge of wheel.	Head acting on wheel, in feet.	Duration of experiment, in minutes.	Revolutions of wheel per minute.	Quantity of water discharged by wheel, in cubic feet per second.	Horse-power developed by wheel.	Percentage of efficiency of wheel.
95	1.077	0.971	17.11	4	153.00	97.00	125.20	66.52
94	1.077	1.017	16.97	3	199.67	101.16	147.66	75.84
93	1.077	1.036	16.94	3	224.33	102.98	156.38	79.04
92	1.077	1.053	16.89	3	239.33	104.50	159.58	79.72
91	1.077	1.061	16.87	3	247.33	105.22	161.17	80.06
89	1.077	1.068	16.81	3	253.67	105.70	161.45	80.12
90	1.077	1.072	16.80	3	259.00	106.08	161.71	80.01
88	1.077	1.079	16.82	4	267.50	106.82	162.15	79.58
87	1.077	1.026	17.05	3	294.67	102.27	125.08	63.23
86	1.000	0.913	17.28	3	147.00	91.65	120.29	66.98
85	1.000	0.957	17.16	2	190.50	95.70	144.34	77.50
84	1.000	0.972	17.14	3	211.67	97.10	152.69	80.89
83	1.000	0.981	17.13	3	225.00	98.03	156.85	82.36
82	1.000	0.990	17.11	3	232.67	98.90	157.96	82.31
80	1.000	0.996	17.09	4	240.25	99.43	160.19	83.13
81	1.000	1.003	17.07	3	247.33	100.07	161.17	83.19
79	1.000	1.004	17.07	4	252.25	100.14	160.55	82.82
78	1.000	1.001	17.13	4	259.00	100.00	157.00	80.82
77	1.000	0.983	17.22	3	268.33	98.43	146.39	76.15
76	1.000	0.911	17.47	4	293.50	91.96	106.75	58.59
106	0.923	0.868	17.32	4	143.25	87.24	115.49	67.39
105	0.923	0.899	17.24	5	176.00	90.12	135.49	76.90
104	0.923	0.920	17.15	4	201.00	91.96	146.21	81.74
101	0.923	0.931	16.93	5	213.20	92.52	148.62	83.66
100	0.923	0.936	16.93	6	220.67	92.96	150.48	84.31
99	0.923	0.942	16.91	4	227.25	93.51	151.52	84.50
102	0.923	0.945	16.93	4	232.00	93.82	151.88	84.81
103	0.923	0.945	17.04	4	235.50	94.14	152.74	83.96
98	0.923	0.945	16.93	4	237.75	93.82	151.32	84.00
97	0.923	0.924	17.02	4	254.50	92.04	138.84	78.15
96	0.923	0.828	17.25	4	288.25	82.47	87.36	54.15
42	0.923	0.870	17.17	3	146.33	87.02	116.20	68.57
41	0.923	0.895	17.10	4	170.00	89.37	130.87	75.51
40	0.923	0.921	17.04	4	202.75	91.80	146.25	82.44
39	0.923	0.928	16.99	3	208.67	92.35	147.99	83.17
35	0.923	0.932	17.03	4	216.25	92.81	150.75	84.10
38	0.923	0.937	16.97	4	220.00	93.20	151.36	84.38
36	0.923	0.939	17.01	4	223.75	93.44	152.58	84.65
34	0.923	0.940	17.02	4	226.25	93.66	150.86	83.45
37	0.923	0.944	16.97	3	238.33	93.90	151.69	83.94
33	0.923	0.921	17.13	4	256.25	92.05	139.80	78.18
32	0.923	0.828	17.27	3	288.00	82.54	87.29	58.99
31	0.923	0.730	17.50	4	334.75	73.75	......	......
74	0.846	0.824	17.46	3	158.67	83.15	120.23	73.02
75	0.846	0.836	17.46	3	176.67	84.35	129.91	77.78
72	0.846	0.861	17.34	5	202.20	86.60	143.40	84.30
70	0.846	0.865	17.33	4	209.00	86.95	145.69	85.25
71	0.846	0.868	17.33	3	215.00	87.24	147.27	85.89
73	0.846	0.870	17.34	4	219.25	87.47	148.19	86.15
69	0.846	0.869	17.32	4	221.25	87.32	147.53	86.01
68	0.846	0.866	17.33	4	227.75	87.02	144.96	84.76
67	0.846	0.858	17.36	4	231.75	86.25	140.48	82.73
66	0.846	0.845	17.39	4	243.75	85.11	132.98	79.22
65	0.846	0.828	17.44	4	256.50	83.44	124.39	75.37

TABLE 2.—(*Continued.*)

Number of experiment.	Proportional Part of: Percentage of full opening of speed-gate.	Percentage of full discharge of wheel.	Head acting on wheel, in feet.	Duration of experiment, in minutes.	Revolutions of wheel per minute.	Quantity of water discharged by wheel, in cubic feet per second.	Horse-power developed by wheel.	Percentage of efficiency of wheel.
64	0.846	0.754	17.59	3	282.00	76.31	85.47	56.15
30	0.769	0.750	17.38	3	141.00	75.52	102.56	68.90
26	0.769	0.766	17.35	3	166.00	77.02	115.72	76.36
27	0.769	0.779	17.32	3	183.00	78.24	124.24	80.84
25	0.769	0.789	17.31	3	194.00	79.25	129.36	83.15
29	0.769	0.793	17.25	4	200.75	79.48	131.42	84.52
28	0.769	0.792	17.26	4	206.00	79.40	131.11	84.36
24	0.769	0.773	17.38	4	226.25	77.82	123.43	80.47
23	0.769	0.735	17.49	3	251.33	74.17	106.64	72.49
22	0.769	0.690	17.56	3	269.67	69.82	81.73	58.78
21	0.769	0.623	17.68	4	323.75	63.27	......	......
20	0.615	0.617	17.91	4	139.50	63.07	88.79	69.31
16	0.615	0.627	17.79	3	158.33	63.81	95.97	74.55
17	0.615	0.634	17.80	3	171.33	64.55	101.26	77.71
15	0.615	0.638	17.73	4	179.50	64.82	103.37	79.31
18	0.615	0.636	17.77	4	183.00	64.74	103.16	79.07
19	0.615	0.634	17.80	2	188.00	64.61	102.56	78.64
14	0.615	0.627	17.72	4	194.50	63.74	100.21	78.24
13	0.615	0.596	17.77	3	218.67	60.60	92.78	75.97
12	0.615	0.563	17.79	4	243.00	57.29	73.65	63.72
11	0.615	0.519	17.92	4	312.00	53.00	......	......
10	0.462	0.452	17.34	3	117.33	45.40	56.90	63.73
5	0.462	0.453	17.02	3	136.00	45.65	61.83	70.17
7	0.462	0.461	17.08	4	146.75	46.04	64.94	72.82
6	0.462	0.462	17.05	4	152.00	46.04	66.34	74.52
4	0.462	0.462	16.92	4	155.25	45.90	65.88	74.79
9	0.462	0.459	17.16	3	162.00	45.94	66.78	74.69
8	0.462	0.457	17.15	3	166.67	45.69	65.67	73.90
3	0.462	0.451	16.98	4	172.25	44.83	62.65	72.57
2	0.462	0.432	17.05	4	217.50	43.04	52.74	63.37
1	0.462	0.404	17.18	5	282.40	40.40	......	......

NOTE.—During the above experiments, the weight of the dynamometer, and of that portion of the shaft which was above the lowest coupling, was 2 600 lb.

With the flume empty, a strain of 0.5 lb., applied at a distance of 3.2 ft. from the center of the shaft, sufficed to start the wheel.

by three-way cocks. By connecting a set of tubes with the vacuum tank, the columns were drawn above the floor level, after which, by closing the cock, they were held in a stationary position. If drawn too high they could be dropped back by opening the cock to the atmosphere. After the columns were once adjusted and the cocks closed, they would stand indefinitely without attention.

This apparatus for the measurement of velocities has been described at some length for the benefit of those who may be interested in the same line of experiments. Lack of space precludes the publication of any of the data obtained, although they are of great interest to the designer, and throw much light on some very obscure points in the theory of turbine design.

REPORT OF THE

BOARD OF WATER COMMISSIONERS

CITY OF OGDENSBURG, N. Y.,

TO THE

HONORABLE MAYOR AND COMMON COUNCIL

RELATING TO

WATER SUPPLY, PROPOSED FILTRATION PLANT AND PLAN FOR FINANCING SAME.

TOGETHER WITH

REPORT OF MESSRS. HAZEN, WHIPPLE AND FULLER, SANITARY ENGINEERS,

AND

COPY OF LETTER FROM THE ENGINEERING DEPARTMENT OF THE STATE BOARD OF HEALTH, ENDORSING AND APPROVING THE SAID SANITARY ENGINEERS' REPORT.

SUBMITTED, FEBRUARY 2ND, 1909.

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SUBMITTED, FEBRUARY 2ND, 1909.

REPORT RELATIVE TO NEW WATER SUPPLY.

At a joint meeting of the Common Council, the Health Board, and the Board of Water Commissioners held more than one year since, the attention of the City authorities was called, by Dr. Eugene H. Porter, Commissioner of Health of the State of New York, to the dangerous and hazardous conditions surrounding the Water Supply of the City.

While for many years those directly chargable with the management of the Water Works, and a considerable number of our citizens, have realized that radical improvement in the conditions around and about the present intake was necessary, in order to remove therefrom the saw-dust and filth nuisance, and while from time to time our medical fraternity has sounded notes of warning against the danger of sewage contamination, but a very small proportion of our Citizens appreciated the real seriousness of the situation as it was outlined and explained by Dr. Porter. His remarks and his warnings were based upon the reports of Engineers and Chemists connected with the State Board of Health, after careful study and investigation of the source of our Water Supply, and frequent and regular analysis of the water of the Oswegatchie River, samples taken from various points between the Railroad Bridge and the Dam.

After listening to and carefully considering Dr. Porter's statements, the Water Board in discharge of what it believed to be its manifest duty, engaged the services of Messrs. Hazen, Whipple and Fuller, Sanitary Engineers, recognized as standing at the head of their profession, to make all necessary surveys, examinations and estimates, and to report their conclusions, findings and recommendations. Their very full and able report was duly received by this Board, and by them published in the City newspapers, to the end that all of our citizens might have opportunity to see and know the views and opinions regarding our present Water Supply, held by Expert Sanitary Engineers and their recommendations for improving the same.

A copy of said report is herewith submitted.

It may appear that the Board of Water Commissioners have moved very slowly in these premises, and that the Engineers' Report, accompanied with the opinion and recommendation of the Commissioners is very late in coming before the Mayor and Council!

We can only say, appreciating the gravity of the situation, they have thought it wise to avoid hasty conclusions. The Board of Water Commissioners regard this, one of the greatest problems the citizens of Ogdensburg have ever been called upon to solve, a problem that in the near future they, and they alone, must solve, or the inevitable consequences, the loss of our largest and steadiest consumer, (the State Hospital) with its annual rate payment of $4,000.00, and a possible dangerous and destructive epidemic of typhoid will surely have to be faced.

The Commissioners have studied this problem in all its phases; they know the regard held by many of our citizens for the soft waters of the Oswegatchie, they know only too well that our taxes are high, and they fully realize that there is a limit of taxation beyond which we cannot go and ought not to go. At the same time they also know that common sense, and due regard for the health, prosperity and happiness of our City and its citizens, demands, that we do not disregard the warnings of those competent to judge of the dangers surrounding us, and that we do not delay action until we are face to face with death and destruction in our homes.

In arriving at their conclusion that, should a filtration plant be installed, the Oswegatchie River should be abandoned as the future source of water supply, and the St. Lawrence River be substituted therefor, the well-established sentiments and prejudices of the majority of the Commissioners had to undergo a complete change before our minds met and the members of the Board as a unit stood ready to advocate the change. When due thought and consideration was given, to the variable and lessening flow of water in the Oswegatchie, the danger of a future shortage in supply, the

fact that a filtration plant for the treatment of its waters, is estimated to cost, when construction and operation are both considered as much or more than the construction and operation of a filtration plant suitable for treatment of the St. Lawrence River water, the fact that the Oswegatchie water would require chemical treatment, whether mechanical or Sand Filtration was adopted, the fact that mechanical filtration has proved far from satisfactory at Watertown where a plant of this type has been installed recently, that its operation involves the steady employment of an experienced Chemist, that the proper treatment of its water supply requires a variable and changing dose of chemicals, according to the changing character of the water, that the life of mechanical filters is estimated to be 20 to 25 years, that the saw-dust, silt and debris with which the Oswegatchie River is at times surcharged would without doubt cause great trouble and expense and might completely clog the filters, finally convinced the Commissioners that a change in our water supply is necessary.

All these unquestionable facts have led the Commissioners to agree that wisdom and past experience dictate that when the citizens of Ogdensburg decide to install a filtration plant, such plant should be located where the supply of water will be for all time unfailing, easily and economically filtered and distributed, and that the filter should be of the practically indestructible sand filtration type.

The saving to all our citizens, that will result from the adoption of filtration, by eliminating dirt and filth from our water supply, and the consequent reduction in plumbers' bills, will, in the opinion of the Commissioners, be an item of no mean proportion.

The impression has prevailed that Bonds necessary to meet the cost of extending and improving our Water Works, can not legally be issued to run for a longer period than 20 years, and must be paid at the rate of 1-20th of the amount of any issue, each year.

The Commissioners are satisfied this is an erroneous impression, a written opinion of the City Attorney, copy whereof is hereto annexed, and the pertinent fact that municipalities in New York State of like classes with Ogdensburg have, within the past two or three years issued bonds of this character, running for 40 years, convinces the members of this Board that they are right in their interpretation of the law, and that 30-year construction bonds can be legally issued as outlined in the plan herewith submitted.

It may appear that the Commissioners have far exceeded the bounds of economy and prudence in adding 10% to the Engineers' estimate of cost of construction, and $1,000.00 to their estimated cost of filter operation. The members of this Board maintain it is far better to overestimate than underestimate on a proposition of this magnitude. Contingencies of a character impossible to foresee may arise, Engineers' estimates may be at fault, and the work once commenced must be carried to completion.

While provision should be made authorizing the issue of Bonds in amounts as recommended in this report, the Bonds should be issued only when and as funds are required. A marked saving in interest will thus result, and if the whole amount authorized is not needed they would not be issued.

The members of this Board believe this is a matter that should be referred to the taxpayers of this city, in such a way as to get an expression of opinion from the largest number, the final decision must rest with them; all that their chosen representatives, the Council, the Water Board and the Board of Health can do is to lay the plain and true facts before them, with such suggestions and recommendations as to them may seem good. With that view and purpose the WATER COMMISSIONERS RECOMMEND, in event that a filtration plant be installed, that such plant be of the type known as slow sand filtration, located above the Ship-Yard, and that the River St. Lawrence be the source of supply, as recommended in the Report of the Engineers, which report has been referred to, and approved by the State Board of Health.

THEY FURTHER RECOMMEND that the cost of the plant with its appurtenances and accessories be financed by the issue of 30-year construction bonds, and 20-year refunding and meter bonds, so arranged as to maturity, that the entire issue of both classes of said bonds, and the present outstanding old Water Bonds, can be paid, principal and interest from the earnings of the Water Works, without recourse to direct taxation or an increase in Water Rates.

This they feel confident can be done, as clearly outlined in the plan and tables herewith submitted.

Respectfully,

JAMES M. WELLS,
FRANK CHAPMAN,
GEORGE F. DARROW,
WILLARD N. BELL,
Water Commissioners.

The table hereto attached shows plan suggested by the Board of Water Commissioners for financing the cost of a Filtration Plant using the St. Lawrence River as the source of supply, in conformity with the suggestions and recommendations contained in the Report of Messrs. Hazen, Whipple and Fuller, Sanitary Engineers.

The estimates and calculations are made on the following assumptions and basis, namely:

FIRST. That a Sand Filtration Plant, with Pumping Station, Stand Pipe, Connections and appurtenances, be constructed in the years 1910 and 1911, and that Bonds to pay for same be issued in 1910.

SECOND. That the cost of the aforesaid plant and appurtenances may exceed $160,000.00, the Engineers' estimate probably 10%, and therefore provision should be made to authorize the issue of $175,000.00 "CONSTRUCTION BONDS" to bear not to exceed 4% interest and to be payable within thirty (30) years.

THIRD. As outlined in the Engineers' report, it will be absolutely necessary, to prevent unreasonable waste of water, and overtaxing the Filtration Plant beyond its capacity that meters be installed as rapidly as is practicable. It is estimated that $20,000.00 will be needed for this purpose.

FOURTH. The amount of old water bonds outstanding in 1911 will be $74,550.00 These bonds mature at the rate of $9,300.00 each year from 1911 to 1917 inclusive, $5,550.00 of said Bonds mature in 1918, $1,550.00 of said bonds mature each year 1919 and 1920, and the remainder thereof, $800.00 mature in 1921.

If the old bonds and the $175,000.00 new 30-year Filtration Construction Bonds, and the $20,000.00 needed for meter installation are to be paid from, and out of the earnings of the Water Works, without recourse to direct taxation or an increase of Water Rates, it will be necessary to refund $40,000.00 of the old bonds, and therefore provision must be made to authorize the issue of $60,000.00 "REFUNDING AND METER BONDS" to bear not to exceed 4% interest and to be payable within twenty (20) years.

FIFTH. The Board of Water Commissioners believe that bonds can be issued as above outlined, in conformity with the Constitution and Laws of the State of New York, and they further believe that the earnings of the Water Works, based on the returns of the past 20 years, with due allowance made for the extra cost of operating the Filtration Plant, will be sufficient to pay the entire cost of a Filtration Plant, (such as is now under consideration,) the cost of meter installation, which must go hand in hand with filtration, and that said earnings can be safely relied upon to pay all of the bonds issued for water purposes, together with the interest thereon, as is clearly shown by the table hereto annexed.

SIXTH. The earning power of the Water Works after the construction of the Filtration Plant, and installation of meters, is estimated on the following basis:

That in 1911 the yearly gross earnings will be $32,000.00 and that based on the average yearly gain for the past 20 years, these earnings may be safely counted on to increase at the rate of $500.00 per year.

That the cost of operation of the present plant, now averages $10,500.00 per year; and

That the additional cost of operation of the Filtration Plant will be $5,500.00 per year, this being $1,000.00 greater than is estimated by the Engineers.

Under the plan as formulated there will, in the judgment of the Commissioners, remain of earnings each year after payment of Bond and Interest charges, a sufficient sum to provide for the necessary and profitable extension of water mains, thereby increasing the earnings of the Water Works.

ESTIMATED CONDITION OF WATER SUPPLY FINANCES FOR EACH YEAR FROM 1911 TO 1940.

Prin.	Rate.	Interest.	Bonds Paid.	
$ 32,000.00	3½%	$1,120.00	$4,000.00	Old Bonds.
7,500.00	3½%	262.00	750.00	Old Bonds.
8,800.00	3½%	308.00	800.00	Old Bonds.
26,250.00	4 %	1,050.00	3,750.00	Old Bonds.
175,000.00	4 %	7,000.00		30 year Filter Bonds.
$249,550.00		$9,740.00	$9,300.00	

DISBURSEMENTS.

Bonds	$9,300.00	
Interest on Bonds	9,740.00	$19,040.00
Current expenses		10,500.00
Filter expenses		5,500.00
Total disbursements		$35,040.00

RECEIPTS.

Water Rates	$32,000.00
Proceeds Refunding and Meter Bonds	7,000.00
Total receipts	39,000.00
Total disbursements	35,040.00
	$ 3,960.00
Say	$ 4,000.00

1912.

Prin.	Rate.	Interest.	Bonds Paid.	
$ 28,000.00	3½%	$ 980.00	$4,000.00	Old Bonds.
6,750.00	3½%	236.00	750.00	Old Bonds.
8,000.00	3½%	280.00	800.00	Old Bonds.
22,500.00	4 %	900.00	3,750.00	Old Bonds.
175,000.00	4 %	7,000 00		Filtration Bonds.
7,000.00	4 %	280.00		Refunding & Met'r B'nds
$247,250.00		$9,676.00	$9,300.00	

DISBURSEMENTS.

Bonds	$9,300.00	
Interest on Bonds	9,676.00	$18,976.00
Current expenses		10,500.00
Filter expenses		5,500.00
Meters		5,000.00
		$39,976.00

RECEIPTS.

Water Rates	$32,500.00
Proceeds Refunding and Meter Bonds	11,000.00
Total receipts	$43,500.00
Total disbursements	39,976.00
Available	$ 3,524.00

1913

Prin.	Rate.	Interest.	Bonds Paid.	
$ 24,000.00	3½%	$ 840.00	$4,000.00	Old Bonds.
6,000.00	3½%	210.00	750.00	Old Bonds.
7,200.00	3½%	252.00	800.00	Old Bonds.
18,750.00	4 %	750.00	3,750.00	Old Bonds.
175,000.00	4 %	7,000.00		Filtration Bonds.
18,000.00	4 %	720.00		Refunding & Met'r B'nds
$248,950.00		$9,772.00	$9,300.00	

DISBURSEMENTS.

Bonds	$9,300.00	
Interest on Bonds	9,772.00	$19,072.00
Current expenses		10,500.00
Filter expenses		5,500.00
Refunding and Meter Bonds		5,000.00
		$40,072.00

RECEIPTS.

Water Rates	$33,000.00
Proceeds Refunding and Meter Bonds	11,000.00
Total receipts	$44,000.00
Total disbursements	40,072.00
Say $4,000 available	$ 3,928.00

1914

Prin.	Rate.	Interest.	Bonds Paid.	
$ 20,000.00	3½%	$ 700.00	$4,000.00	Old Bonds.
5,250.00	3½%	183.00	750.00	Old Bonds.
6,400.00	3½%	224.00	800.00	Old Bonds.
15,000.00	4 %	600.00	3,750.00	Old Bonds.
175,000.00	4 %	7,000 00		Filtration Bonds.
29,000.00	4 %	1,160.00		Refunding & Met'r B'nds
$250,650.00		$9,867.00	$9,300.00	

DISBURSEMENTS.

Bonds	$9,300.00	
Interest on bonds	9,867.00	$19,167.00
Current expenses		10,500.00
Filter expenses		5,500.00
Refunding and Meter Bonds		5,000.00
		$40,167.00

RECEIPTS.

Water Rates	$33,500.00
Proceeds Refunding and Meter Bonds	11,000.00
Total receipts	$44,500.00
Total disbursements	40,167.00
Available	$ 4,333.00

1915.

Prin.	Rate.	Interest.	Bonds Paid.	
$ 16,000.00	3½%	$ 560.00	$4,000.00	Old Bonds.
4,500.00	3½%	157.00	750.00	Old Bonds.
5,600.00	3½%	196.00	800.00	Old Bonds.
11,250.00	4 %	450.00	3,750.00	Old Bonds.
175,000.00	4 %	7,000.00		Filtration Bonds.
40,000.00	4 %	1,600.00		Refunding & Met'r B'nds
$252,350.00		$9,963.00	$9,300.00	

DISBURSEMENTS.

Bonds	$9,300.00	
Interest on Bonds	9,963.00	$19,263.00
Current expenses		10,500.00
Filter expenses		5,500.00
Refunding and Meter Bonds		5,000.00
		$40,263.00

RECEIPTS.

Water Rates	$34,000.00
Proceeds Refunding and Meter Bonds	10,500.00
Total receipts	$44,500.00
Total disbursements	40,263.00
Available	$ 4,237.00

1916.

Prin.	Rate.	Interest.	Bonds Paid.	
$ 12,000.00	3½%	$ 420.00	$4,000.00	Old Bonds.
3,750.00	3½%	131.00	750.00	Old Bonds.
4,800.00	3½%	168.00	800.00	Old Bonds.
7,500.00	4 %	300.00	3,750.00	Old Bonds.
175,000.00	4 %	7,000.00		Filtration Bonds.
50,500.00	4 %	2,020.00		Refunding & Met'r B'nds
$253,550.00		$10,039.00	$9,300.00	

DISBURSEMENTS.

Bonds	$9,300.00	
Interest on Bonds	10,039.00	$19,339.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$35,339.00

RECEIPTS.

Water Rates	$34,500.00
Proceeds Refunding and Meter Bonds	5,000.00
Total receipts	$39,500.00
Total disbursements	35,339.00
Available	$ 4,161.00

1917.

Prin.	Rate.	Interest.	Bonds	Paid.
$ 8,000.00	3½%	$ 280.00	$4,000.00	Old Bonds.
3,000.00	3½%	105.00	750.00	Old Bonds.
4,000.00	3½%	140.00	800.00	Old Bonds.
3,750.00	4 %	150.00	3,750.00	Old Bonds.
175,000.00	4 %	7,000.00		Filtration Bonds.
55,500.00	4 %	2,220.00		Refunding & Met'r B'nds
$249,250.00		$9,895.00	$9,300.00	

DISBURSEMENTS.

Bonds	$9,300.00	
Interest on Bonds	9,895.00	$19,195.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$35,195.00

RECEIPTS.

Water Rates	$35,000.00
Proceeds Refunding and Meter Bonds	4,500.00
Total receipts	$39,500.00
Total disbursements	35,195.00
Available	$ 4,305.00

1918.

Prin.	Rate.	Interest.	Bonds	Paid.
$ 4,000.00	3½%	$ 140.00	$4,000.00	Old Bonds.
2,250.00	3½%	78.00	750.00	Old Bonds.
3,200.00	3½%	112.00	800.00	Old Bonds.
175,000.00	4 %	7,000.00		Filtration Bonds.
60,000.00	4 %	2,400.00		Refunding & Met'r B'nds
$244,450.00		$9,730.00	$5,550.00	

DISBURSEMENTS.

Bonds	$5,550.00	
Interest on Bonds	9,730.00	$15,280.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$31,280.00

RECEIPTS.

Water Rates	$35,500.00
Disbursements	31,280.00
Available	$ 4,220.00

1919.

Prin.	Rate.	Interest.	Bonds	Paid.
$ 1,500.00	3½%	$ 52.00	$ 750.00	Old Bonds.
2,400.00	3½%	84.00	800.00	Old Bonds.
175,000.00	4 %	7,000.00		Filtration Bonds.
60,000.00	4 %	2,400.00	3,000.00	Refunding & Met'r B'nds
$238,900.00		$9,536.00	$4,550.00	

DISBURSEMENTS.

Bonds	$4,550.00	
Interest on Bonds	9,536.00	$14,086.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$30,086.00

RECEIPTS.

Water Rates		$36,000.00
Total receipts	$36,000.00	
Disbursements	30,086.00	
Available	$ 5,914.00	

1920.

Prin.	Rate.	Interest.	Bonds Paid.	
$ 750.00	3½%	$ 26.00	$ 750.00	Old Bonds.
1,600.00	3½%	56.00	800.00	Old Bonds.
175,000.00	4 %	7,000.00		Filtration Bonds.
57,000.00	4 %	2,280.00	4,000.00	Refunding & Met'r B'nds
$234,350.00		$9,362.00	$5,550.00	

DISBURSEMENTS.

Bonds	$5,550.00	
Interest on Bonds	9,362.00	$14,912.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$30,912.00

RECEIPTS.

Water Rates		$36,500.00
Total receipts	$36,500.00	
Disbursements	30,912.00	
Available	$ 5,588.00	

1921.

Prin.	Rate.	Interest.	Bonds Paid.	
$ 800.00	3½%	$ 28.00	$ 800.00	Old Bonds.
175,000.00	4 %	7,000.00		Filtration Bonds.
53,000.00	4 %	2,120.00	6,000.00	Refunding & Met'r B'nds
$228,800.00		$9,148.00	$6,800.00	

DISBURSEMENTS.

Bonds	$6,800.00	
Interest on Bonds	9,148.00	$15,948.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$31,948.00

RECEIPTS.

Water Rates		$37,000.00
Total receipts	$37,000.00	
Disbursements	31,948.00	
Available	$ 5,052.00	

1922.

Prin.	Rate.	Interest.	Bonds	Paid.
$175,000.00	4 %	$7,000.00		Filtration Bonds.
47,000.00	4 %	1,880.00	7,000.00	Refunding & Met'r B'nds
$222,000.00		$8,880.00	$7,000.00	

DISBURSEMENTS.

Bonds	$7,000.00	
Interest on Bonds	8,880.00	$15,880.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$31,880.00

RECEIPTS.

Water Rates		$37,500.00
Total receipts	$37,500.00	
Disbursements	31,880.00	
Available	$ 5,620.00	

1923.

Prin.	Rate.	Interest.	Bonds	Paid.
$175,000.00	4 %	$7,000.00	$	Filtration Bonds.
40,000.00	4 %	1,600.00	8,000.00	Refunding & Met'r B'nds
$215,000.00		$8,600.00	$8,000.00	

DISBURSEMENTS.

Bonds	$8,000.00	
Interest on Bonds	8,600.00	$16,600.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$32,600.00

RECEIPTS.

Water Rates	$38,000.00
Disbursements	32,600.00
Available	$ 5,400.00

1924.

Prin.	Rate.	Interest.	Bonds	Paid.
$175,000.00	4 %	$7,000.00	$	Filtration Bonds.
32,000.00	4 %	1,280.00	9,000.00	Refunding & Met'r B'nds
$207,000.00		$8,280.00	$9,000.00	

DISBURSEMENTS.

Bonds	$9,000.00	
Interest on Bonds	8,280.00	$17,280.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$33,280.00

RECEIPTS.

Water Rates	$38,500.00
Disbursements	33,280.00
Available	$ 5,220.00

1925.

Prin.	Rate.	Interest.	Bonds	Paid.
$175,000.00	4 %	$7,000.00	$5,000.00	Filtration Bonds.
23,000.00	4 %	920.00	5,000.00	Refunding & Met'r B'nds
$198,000.00		$7,920.00	$10,000.00	

DISBURSEMENTS.

Bonds	$10,000.00	
Interest on Bonds	7,920.00	$17,920.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$33,920.00

RECEIPTS.

Water Rates	$39,000.00
Disbursements	33,920.00
Available	$ 5,080.00

1926.

Prin.	Rate.	Interest.	Bonds	Paid.
$170,000.00	4 %	$6,800.00	$6,000.00	Filtration Bonds.
18,000.00	4 %	720.00	4,000.00	Refunding & Met'r B'nds
$188,000.00		$7,520.00	$10,000.00	

DISBURSEMENTS.

Bonds	$10,000.00	
Interest on Bonds	7,520.00	$17,520.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$33,520.00

RECEIPTS.

Water Rates	$39,500.00
Disbursements	33,520.00
Available	$ 5,980.00

1927.

Prin.	Rate.	Interest.	Bonds	Paid.
$164,000.00	4 %	$6,560.00	$7,000.00	Filtration Bonds.
14,000.00	4 %	560.00	4,000.00	Refunding & Met'r B'nds
$178,000.00		$7,120.00	$11,000.00	

DISBURSEMENTS.

Bonds	$11,000.00	
Interest on Bonds	7,120.00	$18,120.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$34,120.00

RECEIPTS.

Water Rates	$40,000.00
Disbursements	34,120.00
Available	$ 5,880.00

1928.

Prin.	Rate.	Interest.	Bonds Paid.	
$157,000.00	4 %	$6,280.00	$7,000.00	Filtration Bonds.
10,000.00	4 %	400.00	4,000.00	Refunding & Met'r B'nds
$167,000.00		$6,680.00	11,000.00	

DISBURSEMENTS.

Bonds	$11,000.00	
Interest on Bonds	6,680.00	$17,680.00

RECEIPTS.

Water Rates	$40,500.00
Disbursements	33,680.00
Available	$ 6,820.00

1929.

Prin.	Rate.	Interest.	Bonds Paid.	
$150,000.00	4 %	$6,000.00	$9,000.00	Filtration Bonds.
6,000.00	4 %	240.00	3,000.00	Refunding & Met'r B'nds.
$156,000.00		$6,240.00	$12,000.00	

DISBURSEMENTS.

Bonds	$12,000.00	
Interest on Bonds	6,240.00	$18,240.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$34,240.00

RECEIPTS.

Water Rates	$41,000.00
Disbursements	34,240.00
Available	$ 6,760.00

1930.

Prin.	Rate.	Interest.	Bonds Paid.	
$141,000.00	4 %	$5,640.00	$9,000.00	Filtration Bonds.
3,000.00	4 %	120.00	3,000.00	Refunding & Met'r B'nds
$144,000.00		$5,760.00	$12,000.00	

DISBURSEMENTS.

Bonds	$12,000.00	
Interest on Bonds	5,760.00	$17,760.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$33,760.00

RECEIPTS.

Water Rates	$41,500.00
Disbursements	33,760.00
	$ 7,740.00

1931.

Prin.	Rate.	Interest.	Bonds Paid.
$132,000.00	4 %	$5,280.00	$13,000.00 Filtration Bonds.

DISBURSEMENTS.

Bonds	$13,000.00	
Interest on Bonds	5,280.00	$18,280.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$34,280.00

RECEIPTS.

Water Rates	$42,000.00
Disbursements	34,280.00
Available	$ 7,720.00

1932.

Prin.	Rate.	Interest.	Bonds Paid.
$119,000.00	4 %	$4,760.00	$13,000.00 Filtration Bonds.

DISBURSEMENTS.

Bonds	$13,000.00	
Interest on Bonds	4,760.00	$17,760.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$33,760.00

RECEIPTS.

Water Rates	$42,500.00
Disbursements	33,760.00
Available	$ 8,740.00

1933.

Prin.	Rate.	Interest.	Bonds Paid.
$106,000.00	4 %	$4,240.00	$13,000.00 Filtration Bonds.

DISBURSEMENTS.

Bonds	$13,000.00	
Interest on Bonds	4,240.00	$17,240.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$33,240.00

RECEIPTS.

Water Rates	$43,000.00
Disbursements	33,240.00
Available	$ 9,760.00

1934.

Prin.	Rate.	Interest.	Bonds Paid.
$ 93,000.00	4 %	$3,720.00	$13,000.00 Filtration Bonds.

DISBURSEMENTS.

Bonds	$13,000.00	
Interest on Bonds	3,720.00	$16,720.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$32,720.00

RECEIPTS.

Water Rates	$43,500.00
Disbursements	32,720.00
Available	$10,780.00

1935.

Prin.	Rate.	Interest.	Bonds Paid.	
$ 80,000.00	4 %	$3,200.00	$13,000.00	Filtration Bonds.

DISBURSEMENTS.

Bonds	$13,000.00	
Interest on Bonds	3,200.00	$16,200.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$32,200.00

RECEIPTS.

Water Rates	$44,000.00
Disbursements	32,200.00
Available	$11,800.00

1936.

Prin.	Rate.	Interest.	Bonds Paid.	
$ 67,000.00	4 %	$2,680.00	$13,000.00	Filtration Bonds.

DISBURSEMENTS.

Bonds	$13,000.00	
Interest on Bonds	2,680.00	$15,680.00
Filter expenses		5,500.00
Current expenses		10,500.00
		$31,680.00

RECEIPTS.

Water Rates	$44,500.00
Disbursements	31,680.00
Available	$12,820.00

1937.

Prin.	Rate.	Interest.	Bonds Paid.	
$ 54,000.00	4 %	$2,160.00	$13,000.00	Filtration Bonds.

DISBURSEMENTS.

Bonds	$13,000.00	
Interest on Bonds	2,160.00	$15,160.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$31,160.00

RECEIPTS.

Water Rates	$45,000.00
Disbursements	31,160.00
Available	$13,840.00

1938.

Prin.	Rate.	Interest.	Bonds Paid.
$41,000.00	4 %	$1,640.00	$13,000.00 Filtration Bonds.

DISBURSEMENTS.

Bonds	$13,000.00	
Interest on Bonds	1,640.00	$14,640.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$30,640.00

RECEIPTS.

Water rates	$45,500.00
Disbursements	30,640.00
Available	$14,860.00

1939.

Prin.	Rate.	Interest.	Bonds Paid.
$ 28,000.00	4 %	$1,120.00	$13,000.00 Filtration Bonds.

DISBURSEMENTS.

Bonds	$13,000.00	
Interest on Bonds	1,120.00	$14,120.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$30,120.00

RECEIPTS.

Water Rates	$46,000.00
Disbursements	30,120.00
Available	$15,880.00

1940.

Prin.	Rate.	Interest.	Bonds Paid.
$ 15,000.00	4 %	$600.00	$15,000.00 Filtration Bonds.

DISBURSEMENTS.

Bonds	$15,000.00	
Interest on Bonds	600.00	$15,600.00
Current expenses		10,500.00
Filter expenses		5,500.00
		$31,600.00

RECEIPTS.

Water Rates	$46,500.00
Disbursements	31,600.00
Available	$14,900.00

SUMMARY OF PLAN FOR FINANCING NEW AND OLD WATER WORKS DEBT.

Date.	Old Bonds Outstanding.	Filtration Constuction Bonds Outstanding.	Refunding and Meter Bonds Outstanding.	Total Bonds Outstanding.	Payment Account Bonds.	Payment Account of Interest.	Refunding & Meter Bonds, How and When Issued: Refunding.	Refunding & Meter Bonds, How and When Issued: Meter.	Date.
1911	$74,550	$175,000	$	$249,550	$ 9,300	$ 9,740	$ 7,000	$	1911
1912	65,250	175,000	7,000	247,250	9,300	9,676	6,000	5,000	1912
1913	55,950	175,000	18,000	248,950	9,300	9,772	6,000	5,000	1913
1914	46,650	175,000	29,000	250,650	9,300	9,867	6,000	5,000	1914
1915	37,350	175,000	40,000	252,350	9,300	9,963	5,500	5,000	1915
1916	28,050	175,000	50,500	253,550	9,300	10,039	5,000		1916
1917	18,750	175,000	55,500	249,250	9,300	9,895	4,500		1917
1918	9,450	175,000	60,000	244,450	5,550	9,730			1918
1919	3,900	175,000	60,000	238,900	4,550	9,536			1919
1920	2,350	175,000	57,000	234,350	5,550	9,362			1920
1921	800	175,000	53,000	228,800	6,800	9,148			1921
1922		175,000	47,000	222,000	7,000	8,880			1922
1923		175,000	40,000	215,000	8,000	8,600			1923
1924		175,000	32,000	207,000	9,000	8,280			1924
1925		175,000	23,000	198,000	10,000	7,920			1925
1926		170,000	18,000	188,000	10,000	7,520			1926
1927		164,000	14,000	178,000	11,000	7,120			1927
1928		157,000	10,000	167,000	11,000	6,680			1928
1929		150,000	6,000	156,000	12,000	6,240			1929
1930		141,000	3,000	144,000	12,000	5,760			1930
1931		132,000		132,000	13,000	5,280			1931
1932		119,000		119,000	13,000	4,760			1932
1933		106,000		106,000	13,000	4,240			1933
1934		93,000		93,000	13,000	3,720			1934
1935		80,000		80,000	13,000	3,200			1935
1936		67,000		67,000	13,000	2,680			1936
1937		54,000		54,000	13,000	2,160			1937
1938		41,000		41,000	13,000	1,640			1938
1939		28,000		28,000	13,000	1,120			1939
1940		15,000		15,000	15,000	600			1940

HAZEN & WHIPPLE,
Consulting Civil Engineers,
103 Park Avenue,
New York.
July 10, 1908.

Board of Water Commissioners, Ogdensburg, N. Y.:

Dr. Willard N. Bell,
Mr. Frank Chapman,
Mr. George F. Darrow,
Mr. James M. Wells.

Gentlemen: In accordance with your instructions I am presenting the following report on the best means of improving the quality of the Ogdensburg water supply, and upon other improvements connected therewith.

RECOMMENDATIONS:

I recomend the abandoning of the present supply from the Oswegatchie River, for reasons given hereafter, the securing of a new supply from the St. Lawrence River; the construction of sand filters for purifying this water; the construction of a pumping station on the shore of the St. Lawrence; and the erection of a standpipe on the hill above the city quarry.

The estimated cost of all improvements is $160,000, of which $140,000 is for works necessary to the new supply with purification works, and $20,000 for the standpipe and extra pumping, piping and other incidentals connected therewith.

POPULATION AND CONSUMPTION:

The present population of the city is about 15,500. The average rate of growth for the past 25 years has been about 1 per cent. per year.

The present average daily consumption of water is about 2,250,000 gallons, of which 250,000 is supplied to the State Hospital. Deducting this quantity from the total average consumption, the average daily consumption for the city is 1,900,000 gallons, or about 140 gallons per capita. Only a very few meters are in use.

In the past with the small cost of pumping and no purification, the waste of water has not been of great importance. With the addition of purification works this becomes a much more important matter. The cost of works to be constructed, as well as the cost of operating them, increases with the amount of water pumped, and all waste will be a total loss to the city. The best way to stop waste is to put meters on the services. The installation of meters is increasing rapidly in the cities in this country, particularly in those cities where the cost of securing, pumping or purifying the water has been increased. With the present large consumption of water in Ogdensburg the installation of meters at this time will effect a material saving to the city and to the consumers. It is necessary to take up this matter at the present time in order to avoid building purification works and other improvements of greater capacity than needed to supply the water that is actually used.

CAPACITY OF WORKS REQUIRED:

The present annual average consumption is 2,250,000 gallons. During some months of the year the average is probably 20 per cent. greater, and during some days the consumption is probably fully 50 per cent. in excess of the annual average, or nearly 3,500,000 gallons. The construction of a pure water reservoir and a standpipe will balance the hourly fluctuations and they may be disregarded but the works must be sufficient to supply the maximum days' use.

For the present consumption a plant of 3,500,000 gallons capacity will suffice, and a plant of this capacity is recommended. With it meters must be installed at a rate sufficient to cut off waste so that the increase in use

due to increased population and other causes will not increase the consumption. For the present rate of growth of the city the gradual installation of meters should suffice to keep this consumption from increasing for about 20 years and in the interval somewhat lower rates may be reached.

SOURCE OF SUPPLY:

The supply is taken from the Oswegatchie River from an intake opposite the pumping station in a pond formed by the dam. The catchment area of the river is about 1,750 square miles. There is a rural population upon most of this area, with many villages. Among these may be mentioned Heuvelton, 9 miles; Rensselaer Falls, 15 miles; Gouverneur, 30 miles above the intake. The latter is a village of about 4,000 population provided with a sewerage system discharging directly to the river.

The conditions of the catchment area are such that the water is not suitable for domestic use. Moreover, the present position of the intake is such that there is local pollution of a very serious character from the houses in the city of Ogdensburg only a few hundred feet from the intake and above it. The change in location of the intake to a point above these houses is essential if this water is to be used, but such change in the location would only relieve the danger from this local source and purification is clearly needed on account of the pollution of the water from sources farther up the river.

Aside from the poor sanitary quality of the water, the color is always high, and at times very high, and there are also disagreeable tastes and odors during some periods of the year. The hardness of the water varies materially at different times of the year. It is never very hard. The turbidity increases considerably during floods, but ordinarily is not high.

"SAW-DUST."

A great deal of trouble has been experienced in the city and at the pumping station with debris in the river which is commonly called "saw-dust." It consists of water-logged chips which have evidently accumulated at the bottom of the river at various points and which has been stirred up by the movement of the ice, particularly anchor-ice, and swept down to the intake during floods. This "saw-dust" has at times clogged the 30-inch intake pipe. It has caused a great deal of trouble in the water-wheels, screens, etc., and has also plugged many service pipes, and not infrequently the large mains of the system. Altogether the expense caused by the "saw-dust" nuisance has been a very large item in the cost of operation of the works, and a much larger one to the property owners of the city. There will be a large saving to the city, and a larger one to the property owners with the elimination of this trouble. The last report of Mr. Lord, the Superintendent of Water Works, included an item of $1,048 for expense due to "saw-dust" and anchor-ice, and a considerable amount of this will be saved. It is impossible to estimate the saving to the property owners, but it will certainly be large, as the plugging of service pipes is a well recognized source of trouble and expense.

The Oswegatchie water destroys the service pipes and plumbing of the city rapidly so that renewals and repairs are a large item of expense to the property owners. The cast-iron mains are also tuberculated to some extent by this water and will have to be renewed at an earlier date than with a water having less action upon them.

BLACK LAKE:

The storage of the water in Black Lake is one of the causes of the color of the water. The lake has a peaty bottom and a large dredge has been built to excavate and handle this peat. This project is a very large one, and, if successful, would mean a large increase in the population of the catchment area with consequent additional pollution. The city cannot afford to oppose this development, as it will be very much to its advantage to have it successfully carried through. A considerable amount of money

has already been expended on the construction of the dredge and the project has been carried to such a point that it cannot be neglected in considering the source of supply.

PUMPING STATION AND EQUIPMENT:

The city owns a share in the water power on the Oswegatchie River by which the pumps are operated for about eight months during the year. During the remainder of the time the water is pumped by steam. There are two 48-inch Victor turbines operating under a head of about ten feet. The wheels operate a power pump of about five millions gallons capacity. The steam equipment consists of two vertical marine boilers, each of 125 horse power and one Snow triple expansion duplex pump of six million gallons capacity. The system is one of direct pumping. At the present time there is no reserve for the Snow pump and any break during time of low water when the power pump could not be used would be a very serious matter. Additional pumps for this use are urgently needed and must be included in any improvement, though they form no part of the purification works.

STANDPIPE:

A standpipe to furnish storage to equalize the draft on the pumps is much needed. There are several locations that could be utilized. The highest point is on the hill above the City Quarry. This elevation is about 80 feet above the pumping station floor. A standpipe erected there, 50 feet high, and 40 feet in diameter, would have a capacity of nearly 500,000 gallons. Other locations less desirable are on Caroline street, 45 feet above the pumping station floor, and on Plover Hill, 50 feet above. At these last mentioned locations the lower part of the standpipe would be of but little value, and a height of at least 75 feet would be required, of which the lower 35 would not be available for furnishing water under satisfactory pressure to the higher portions of the city.

The erection of a standpipe would make the operation of the works very much simpler and safer. It would equalize the draft of the pumps and allow the pumps to be temporarily shut down for repairs.

The best location of the standpipe depends upon the source of supply that is selected. For the present supply the one on Caroline street would be the most convenient. It is near the pumping station, which is desirable, as the standpipe must be disconnected from the system during fires, as the pressure from it would not be sufficient for fire service. It would, however, serve as a storage for water for use by the fire engines in case the pumps were not running. If the standpipe should be erected on Caroline street it should be of unusually attractive design of concrete and steel. For the supply from the St. Lawrence River, the location of the standpipe above the City Quarry will be best. In such a case the standpipe might well be of steel, as the St. Lawrence River water will not seriously attack it if properly protected and kept in repair.

PURIFICATION WORKS REQUIRED FOR OSWEGATCHIE RIVER WATER:

The construction of a V-shaped crib at the end of the intake, properly arranged, would exclude much of the "saw-dust" from the intake. The remaining portion of the "saw-dust" would be removed in the coagulating basin. The tastes and color would be reduced by aeration during such parts of the years as required. Mechanical filtration would remove the color from the water and also the effect of pollution in the river. It is essential, however, that the plant should be properly operated by a competent superintendent, who must be a trained chemist and bacteriologist.

Sand filters, combined with sedimentation, would effectually remove the pollution from the river but would not remove the color. By the construction of a large coagulating basin and the use of coagulant this color could be removed.

MECHANICAL FILTRATION OF THE OSWEGATCHIE RIVER WATER.

General Description of Works Required:

The filtration plant could be best located at a distance of about 3,000 feet above the present pumping station, on the east side of the river. The intake would be a 24-inch pipe carried about 100 feet into the river. At the end of the pipe would be constructed a timber crib, V-shaped and about 25 feet long, so arranged that the bulk of the "saw-dust" would be excluded from the pipe. A small pumping station would be erected near the shore, in which would be installed two centrifugal pumps, each with a capacity of three million gallons per day, and connected with motors. These motors would be operated by electricity from dynamos to be installed in the present pumping station, run by water power when there is water enough to operate the water-wheels, and at other times by steam turbines, to be installed in the present pumping station.

A 24-inch force main would lead from the pumping station to the aerator and to the coagulating basin. During such portions of the year as it was found to be desirable, the water would be pumped to the aerator. At other times it would be pumped to the coagulating basin direct.

The coagulating basin would have a capacity of 600,000 gallons or a little over four hours' supply at the nominal rate, and would be arranged in two compartments to facilitate cleaning.

From the coagulating basin the water would flow to reinforced concrete filters, with a net filtering area of about 1400 square feet. After passing through these the water would be collected in the pure water reservoir of about 1,000,000 gallons capacity. A building would be constructed over the filters in which the apparatus for supplying the coagulant and for operating the filters would be placed. In this building would be a laboratory and an office for the superintendent of the plant.

From the clear water basin the water would flow through a 24-inch main running along the bank of the river and thence along Water Street, laid low enough so that the water would flow by gravity to the pumping station. This 24-inch main would be connected to the present 30-inch intake pipe near the present intake chamber. In the present pump house there would be installed two 25-horse power dynamos, and two 30-horse power steam turbines. The dynamos would be connected to both the water-wheels and the steam turbines. A transmission line would be built from the present pump house to the new pump house for furnishing power to the new pumps.

At some available point on the hill on Caroline Street a standpipe would be built and connected with the 16-inch main of the distribution system. This standpipe would be of concrete-steel and about 75 feet high, and of attractive design. Arrangements would be made so that the standpipe could be disconnected from the system during fires, so that fire pressure could then be maintained directly from the pumps. If a satisfactory location could not be secured on Caroline Street, the site on Plover Hill could be utilized at somewhat greater expense.

A new triple expansion duplex pump of a capacity of three million gallons daily would be installed in the present pumping station. This pump would be used for the regular service during periods when the water power was not available. The present Snow pump would be held in reserve for fire purposes and for use in case of accident to the new pump.

The plant to be installed at present would have a nominal capacity of 3,500,000 gallons daily, but should be designed to provide for future extensions and only those parts need be built now that would be necessary to maintain the 3,500,000 rate, the addition to be made as the city required.

The estimated cost of a mechanical filter plant, to purify the Oswegatchie River water, with standpipe, pumps and all appurtenances is as follows:

ESTIMATED COST OF CONSTRUCTION.

Land		$ 1,500
Pumping station building	$2,000	
Low lift, centrifugal pumps, 2 each of 3 M. G. cap.	3,000	5,000
Intake, pipe to filter and connections		2,000
Aerator		2,000
Mechanical filters, with appurtenances, complete, 3,500,000 gallons capacity; including a pure water reservoir of 1,000,000 gallons capacity		56,000
Piping to pumping station, 3,000 feet of 24-inch@$4.50		13,500
Reserve pump, 3.0 million capacity	$7,500	
Dynamos, steam turbines and transmission line	4,000	11,500
Standpipe and connections		16,000
		$107,500
Engineering and contingencies, 15%		16,125
Total estimated cost of construction		$123,625

ESTIMATED ANNUAL COST OF OPERATION.

Sulphate of alumina, 120 tons per annum at $23	$ 2,760
Salary of Chemist and Superintendent	1,200
Attendance for filters, 3 at $50 per month	1,800
Extra labor at pumping station	400
Additional coal used	240
Annual cost of operation	$ 6,400
Capital charges at 5 % on $124,000	6,200
Total estimated annual cost of operation, including capital charges	$ 12,600
Cost per million gallons for purification, additional pumping and storage, average consumption of 2.25 million gallons daily	$ 15.35

CARRYING INTAKE ABOVE THE CEMETERIES:

It would not be necessary to carry the intake above the Cemeteries. The drainage from them is not a menace to the health of the city. In fact, their location above the intake may be considered rather as an advantage inasmuch as they effectually prevent the building of houses along the river bank which would be a serious menace to the supply. There might be some advantage in carrying the intake further up to secure a better bottom for the intake crib and possibly avoid some of the trouble with the "saw-dust." It is not certain that this would be any material advantage and the additional cost would not be justified. A project to carry the intake above the cemeteries was investigated and an estimate prepared. The most favorable location would be at a distance of 6,000 feet above the present pumping station on the west bank of the river. The low lift pumps and filters could be located there with a 24-inch pipe connected to the present pumping station. The works required and the operation would be much the same as those given in detail above. The additional cost would be about $16,000.

EXPERIENCE WITH WATER LIKE OSWEGATCHIE WATER:

A mechanical filter plant of six million gallons nominal capacity was installed at Watertown in 1904, and has been operated for nearly four years. The plant has been very successful and has greatly improved the water. Since its installation the death rate from typhoid fever has been reduced from an average of 97 to 100,000 to about 27 per 100,000. The water has been made clear and colorless. In some ways, however, this filtered water has given trouble to the consumers. The filtered water, colorless as it leaves the filters and as it flows from the cold water taps has in many houses been found to have a very disagreeable red color as it comes from

the hot water pipes. This color is due to iron taken up by the action of the water on the pipes, and has been the cause of many complaints. Troubles with the plumbing, particularly the water closet tanks have also increased since the installation of the plant, more renewals and repairs have been necessary and many complaints have been made on that score.

The water from the Black River is very similar in quality to that of the Oswegatchie, and the trouble in Watertown would probably be experienced in Ogdensburg under like circumstances. The present cost of repairs to the plumbing due to the action of the water in the pipes in Ogdensburg is high, and it would surely be increased with the purification of the water from the Oswegatchie River.

At Watertown there was no other available supply to be obtained without large expense to the city, so that the construction of the plant was fully jusified. The conditions at Ogdensburg are, however, very different with so good a supply available as the St. Lawrence River.

SAND FILTERS WITH COAGULATION FOR OSWEGATCHIE RIVER WATER.

General Description of Works Required:

The general location of the works would be as given above for a mechanical plant. The intake, aerator, pumping equipment, piping and standpipe would be practically the same as for a mechanical plant.

The water would be lifted by the low-lift pumps to the aerator, when required, and at other times to the coagulating basin direct. The coagulating basin for use with sand filters would have to be much larger than would be required for the mechanical plant in order to provide a more thorough sedimentation before the water was allowed to flow on to the filters. This would be necessary to avoid the rapid clogging of the sand filters. With mechanical filters the washing of the beds at frequent intervals is provided for, but no such means would be practical on the large sand filters. A coagulating basin of not less than 3,000,000 gallons capacity would be required.

This basin could be an open one, thus reducing the cost. The filters would be covered masonry structures consisting of four units each of 0.2 acres in area. The pure water reservoir would be a covered masonry structue of a capacity of 1,000,000 gallons.

ESTIMATED COST OF SAND FILTERS COMBINED WITH A COAGULATION FOR THE PURIFICATION OF THE OSWEGATCHIE RIVER WATER.

ESTIMATED COST OF CONSTRUCTION.

Land		$ 1,500
Pumping station building	$2,000	
Low lift centrifugal pumps, each of 3 M. G. cap	3,000	5,000
Intake, pipe to filters and connections		2,000
Aerator		2,000
Open coagulating basin, capacity 3,000,000 gallons with coagulating apparatus complete		25,000
Sand filters, 4 units each of 0.2 acres in area		60,000
Pure water reservoir; cap. 1,000,000 gallons		12,000
Piping to pumping station, 3,000 feet of 24-inch at $4.50		13,500
Reservoir pump	$7,500	
Dynamos, steam turbines and transmission line	4,000	11,500
Standpipe and connections		16,500
		$149,000
Engineering and contingencies, 15%		22,350
Total estimated cost of construction		$171,350
Say		$172,000

ESTIMATED ANNUAL COST OF OPERATION.

Sulphate of alumina, 120 tons at $23	$ 2,760
Supervision, attendants, extra labor on pumps and analysis	2,400
Cleaning filters at $1.50 per million gallons	1,200
Additional coal used	240
	$ 6,600
Capital charges, 5% on $172,000	8,600
Total estimated annual cost of operation, including capital charges	$ 15,200
Cost per million gallons for purification, additional pumping and storage	$ 18.50

Such a development would make the Oswegatchie water satisfactory as to sanitary quality, would remove the color, and the aeration would reduce the taste and odor. The project is not considered further as the cost is so much greater than that for mechanical filtration for this water that such works would not be justified.

SAND FILTRATION WITHOUT COAGULATION FOR THE OSWEGATCHIE WATER:

It has been suggested that the color of the water is not objectionable to the people of Ogdensburg, that slow sand filters to remove the pollution would be sufficient for the present, and that coagulation could be added in the future. Without preliminary treatment of the water the rate at which the filters could be operated would have to be reduced and a greater filtering area be provided. With the St. Lawrence river water and with the Oswegatchie water treated with a coagulant a rate of five million gallons per acre daily could be used. With Oswegatchie River water in its raw state, this rate should not exceed three million gallons per acre daily. This rate of three million gallons per acre daily is the one generally used in sand filtration for such water as the Hudson River, and other rivers subject to turbidity and high pollution at certain periods. The sand would require washing more frequently with the use of raw water with a consequently increased cost.

The cost of works for slow sand filters without coagulation is estimated as follows:

Land		$ 1,500
Pumping station building	$2,000	
Low lift centrifugal pumps, 2 each 3 M. G. capacity	3,000	5,000
Intake, pipe to filters and connections		2,000
Aerator		2,000
Sand filters, 4 units, each 0.3 of an acre in area		90,000
Pure water reservoir, 1,000,000 gallons capacity		12,000
Piping to pumping station 3,000 feet of 24-inch at $4.50		13,500
Reserve pump		7,500
Dynamos, steam turbines and transmission line		4,000
Standpipe and connections		16,500
		$154,000
Engineer and contingencies, 15%		23,100
		$177,100

ESTIMATED ANNUAL COST OF OPERATION.

Extra labor, on pumps, supervision, attendants and analysis	$ 1,800
Cleaning filters, $2.00 per M. G.	1,600
Extra coal	240
	$3,640
Capital charges, 5% on $177,100	8,850
	$12,490

Such a development, while it would remove the pollution from the river, would not prove satisfactory in other respects. The Oswegatchie River water is not a satisfactory water to treat hy means of slow sand filters without coagulation. Experience in other places with supplies like the Oswegatchie has been that ultimately coagulations or other preliminary treatment of the water has been adopted.

The cost of construction for this project is high and the operating expenses with capital charges are about the same as for the mechanical filters. This project could only be considered as a temporary arrangement and coagulation would ultimately have to be added at a further large expense.

The Oswegatchie River water can be most economically treated hy mechanical filters and that project only is considered in comparison with the St. Lawrence supply.

SUPPLY FROM ST. LAWRENCE RIVER.

The water of the St. Lawrence river is clear, and free from color, taste and odor. There is some pollution in the river from towns above. Of these, Morristown is the nearest town, about 12 miles above on the south side of the river. The population is about 500. Brockville is nearly opposite Morristown, on the north side of the river. Brockville has a sewerage system discharging to the river. The quantity of the Brockville sewage reaching the Ogdensburg intake would, however, not be a serious matter. The Skillings, Whitney and Barnes lumber yard is about 3,000 feet above the proposed intake and some 200 to 300 men are employed in the lumber yard. This small amount of pollution would not be serious in such a large river after filtration through sand filters. Steps should, however, be taken to have as little pollution from this source as possible.

The St. Lawrence River would not be satisfactory from a sanitary standpoint without filtration, but with it would be entirely so. In its raw state it is very much superior to the Oswegatchie water. The St. Lawrence water has a hardness of about 85 to 100 parts per million, while that of the Oswegatchie varies from 20 to 45. The St. Lawrence River water is much the same in hardness and in appearance throughout the year, while that of the Oswegatchie is very variable. In this respect St. Lawrence water is superior and easier to purify. In the same way the St. Lawrence, while carrying some pollution at all times, is of such great volume that the pollution is more dilute and more constant and more readily removed than in the case of the Oswegatchie water, where during floods large quantities of pollution are brought down. The only advantage that the Oswegatchie has over that of the St. Lawrence is in the matter of hardness. This is, however, of considerable moment, both for domestic and for manufacturing purposes, as a soft water leads to, material saving in use in boilers and in many domestic uses.

GENERAL DESCRIPTION OF PLANT TO BE INSTALLED FOR ST. LAWRENCE RIVER SUPPLY.

The plant will be located at a point a short distance above the "Ship-Yard," upon low land between the river and the railroad. The intake will consist of a 24-inch pipe reaching about 300 feet into the river, terminating in a submerged crib.

A pumping station will be built near the shore in which will be installed two low lift centrifugal pumps for pumping the raw water to the filters, and two turbine pumps for pumping the pure water to the standpipe. Each pump will have a capacity of three million gallons. One of the low lift pumps and one of the high lift pumps will be equipped with electric motors. The other two will be equipped with steam turbines. Two 100 horse-power boilers will be installed to run the steam turbines.

In the present pumping station a 125 horse-power dynamo will be installed which will be connected with both the water wheels and to a new steam turbine. A transmission line will connect the two stations. When there is sufficient water in the Oswegatchie, the pumping will be done by

electricity generated by the water power at the present pumping station. The steam equipment at the new station will then serve as reserve in case of accident to the electrical equipment. During the dry period, when the water power is not sufficient, the steam equipment at the new station will be regularly used with the electrical equipment, operated by the steam turbine serving as reserve.

From the pumping station the low lift pumps will lift the water to the sand filters, which will consist of four units each 0.2 of an acre in area. From the filter the water will flow to the pure water reservoir of 500,000 gallons capacity; and thence to the pumping station, where it will be lifted to the standpipe, of about 500,000 gallons capacity, built on the hill above the City Quarry. From the standpipe it will flow through a 20-inch main to the present pumping station, where it will be connected with the present force main. Water in the standpipe will furnish sufficient pressure for ordinary use, and the 20-inch pipe will be of sufficient size to supply water for such use without excessive loss of head, and will deliver to the present pumping station more than the maximum amount of water required for fires. The present pumping equipment will he held in reserve for increasing the pressure of the water during fires. The arrangement of the gates will be such that water will ordinarily flow past the present pumps, but so that they can be readily connected in case of fire.

The estimated cost of sand filters for the purification of the St. Lawrence River water is as follows:

ESTIMATED COST OF CONSTRUCTION.

Land		$ 1,000
Intake, 500 feet, 24 inch and crib	$ 3,000	
Pipe to standpipe, 2,300 feet of 20-inch, (part rock) at $4	9,200	
Pipe to present pumping station, 20 inch, 4,800 feet (part rock and river crossing) at $4	19,200	31,400
PUMPING STATION ON BANK OF ST. LAWRENCE.		
Low lift pumps, two 3 M. G. capacity, lift 10 feet	$ 2,000	
Two 3 M. G. capacity, life 150 feet	10,000	
Two 100 horse-power boilers	4,000	
Building and connections	8,000	$ 24,000
Filters, four units, each 0.2 acre		60,000
Pure water reservoir, 500,000 gallons, 1-7 of 1 day supply		7,000
Dynamo and steam turbine at present pumping station	$5,000	
Other changes at present station	1,500	6,500
Standpipe, 500,000 gallons capacity		7,500
Transmission line, connections, etc		1,600
		$139,000
Engineering and contingencies, 15%		20,850
Total estimated cost of construction		$159,850
Say		$160,000

ESTIMATED ANNUAL COST OF OPERATION.

Additional coal due to maintaining two stations and somewhat higher lift; for four months, 200 tons at $3.50		$ 700
(Soft coal could be used at the river station without objection, so that if the use of hard coal must be continued at the present station there will be a saving rather than a loss.)		
Additional labor, 3 men at $50 per month	$1,800	
Extra labor during use of steam pumps	400	2,200
Cleaning filters $1.50 per million gallons		1,200
Analysis and supervision		400
		$ 4,500
Capital charges 5%		8,000
Total estimated cost of operation		$ 12,500
Cost per million gallons for purification, additional pumping and storage; average consumption of 2.25 million gallons		$ 15.20

WELL SUPPLY.

There are no successful well supplies in the vicinity of the size required by Ogdensburg, nor are there any wells developed to indicate that such a supply could be obtained. The formation of the country is limestone. If such a supply could be obtained it would be very hard. The construction of works to develop it would be expensive and the cost of operation high and the water would be less satisfactory than the supply recommended. At the best it would be an expensive experiment for the city to try to develop a supply of water by wells.

FINANCIAL.

The following data as to the finances of the Water Department is taken from the 1907 report of Mr. Lord, your Superintendent:

Outstanding Bonds		$107,450
Total receipts for 1907		$30,629
Disbursements for 1907—		
Operating expenses and service pipes	$12,287	
Improvements	6,111	
Interest	4,138	
Bonds	10,300	32,836

It is stated that the operating expenses were higher than for previous years , on account of the increased cost of steam pumping due to the long dry period when water power was not available, and to the increased cost due to using hard coal. The cost of this steam pumping is given as $3,606, and it is stated that it is nearly double what it has been during other years.

From this data the average cost of operation of the plant under average conditions may be taken as $10,500, exclusive of improvements or interest. The estimated additional cost of operation due to the proposed improvements is $4,500, making a total of $15,000. The capital charges on the investment of $267,450 (cost of proposed work plus present bonds outstanding) taken at 5% to allow for a sinking fund, will be $13,375, making a total estimated annual cost of $28,375. With the total receipts of $30,629 as in 1907, this will leave a surplus of $2,254 to be applied to improvements.

With the proposed improvements the water will be of greater value, and it is probable that the State Hospital will be willing to pay more for the water supplied to them. The installation of meters will more than pay for themselves in the reduction of the amount of water wasted, and the cost of installing them need not be included in this estimate, which is based on present conditions.

The outstanding bond issue represents about $8 per capita. This does not represent the value of the plant, as a large amount of bonds has been paid off and many improvements made from the receipts of the Water Department. With the proposed improvements the total bond issue would be about $20 per capita, which is not large. Deducting the $4,000 received from the State Hospital the receipts from the city are $26,629, or less than $2 per capita. The average of American cities with municipal ownership of plants is about $2.50. When it is considered that the consumption of water is much above the average, this rate is very low.

The finances of the Water Department will suffice to build the works recommended and to pay the annual cost of operation, interest charges and provision for sinking fund, with an estimated surplus of $2,000. Needed improvements may be provided for this surplus by rates from new business secured, increased receipts from the State Hospital, or by proceeds of a further bond issue. In this way all may be carried by careful management. Otherwise, either a 10% increase in the present rates, which are below average, or a hydrant rental paid by the city during such period as may be necessary will suffice to put the works in a strong financial position. The saving to the property owners from the reduction of the expense of renewals and repairs now caused by the "saw-dust" and rapid action of the water on the pipes and plumbing fixtures should far more than compensate for such an increase in rates.

COMPARISON OF PROJECTS.

Sanitary Quality:

In its raw state the St. Lawrence water is superior in sanitary quality. The pollution is never great, and with the large volume of water flowing is quite constant, and readily removed by sand filtration. After such filtration it will be entirely satisfactory for domestic use.

The Oswegatchie River water treated through mechanical filters would also be of a good sanitary quality. This method of purification depends entirely upon the proper and continuous application of a chemical to the water and to the proper operation of the filters. In well designed plants this operation is made as simple as possible, but considerable delicate apparatus is necessary. Sand filters are comparatively simple to operate.

The pollution in the Oswegatchie water is variable. The volume of flow is variable and small as compared with the St. Lawrence, and at times the water is much more polluted and the pollution more difficult to remove. The purified St. Lawrence water is clearly to be preferred to the purified Oswegatchie water as to sanitary quality.

Color, Taste and Odor:

The St. Lawrence water is free from color, taste and odor, while the Oswegatchie water is objectionable in all these qualities. Mechanical filtration, combined with aeration, would reduce the color, taste and odor, but incidental minor troubles are likely to develop with such treatment of a water like the Oswegatchie.

Action of Pipes and Plumbing:

The raw Oswegatchie water acts freely on pipes and plumbing at the present time, and with mechanical purification such action would probably be increased materially. The St. Lawrence water would be much superior in this respect, as its action would be inconsiderable. The use of the St. Lawrence water would effect a material saving and is an important point in favor of the St. Lawrence supply.

"Saw-Dust" and Turbidity:

The St. Lawrence water is free from turbidity, while that of the Oswegatchie contains both turbidity and "saw-dust" at times. These could be removed by the plant proposed for the Oswegatchie supply, but would cause more or less trouble in operating the plant.

Hardness:

The St. Lawrence water has on an average about 60 parts per million greater hardness than the water from the Oswegatchie. This greater hardness is objectionable, as a hard water is less desirable for domestic and manufacturing use and causes an increase in expense for soap and boiler compounds.

Cost of Operation:

The operating expenses including capital charges with allowance for sinking fund are shown in the schedule and are practically the same for the two projects. The first cost of the St. Lawrence supply is $160,000, as against $124,000 for the Oswegatchie supply, but the operating expenses for the St. Lawrence supply are less, so that as an investment the two projects may be considered equal.

Summary:

The many points of superiority of the St. Lawrence water over that of the Oswegatchie far more than offsets the one disadvantage of a greater hardness.

The St. Lawrence water purified will be clear, colorless and pure and will be in all respects a good supply. The Oswegatchie, while it could be purified and greatly improved over the present supply, would be more or less troublesome in many respects.

It is clear that the St. Lawrence supply should be adopted and the value of having the pure water will be worth many times the cost to the people of Ogdensburg.

I beg to acknowledge my obligations to Superintendent Harry A. Lord, and to all the members of the Water Board for courtesies and aid in preparing this report.

Respectfully submitted,

(Signed) WESTON E. FULLER.

HAZEN & WHIPPLE,
Consulting Engineers,
103 Park Avenue,
New York.

(Copy) June 22, 1908.

To the Honorable, the Board of Water Commissioners, Ogdensburg, N. Y.:

Gentlemen—When the matter of this investigation came up, Mr. Lord wrote me personally, saying that he hoped I could come to Ogdensburg and go over the ground with you. I wished very much to do this, but was unable to promise it, as the Portland work and the Denver work have taken a large part of my time and have continued to do so up to the present time.

Mr. Fuller has been over all the matters, and has discussed them with Mr. Whipple and myself, and we are entirely agreed as to what it is best for you to do. As we believe you wish to have the report at an early date, and as there is no opening which will allow me to go to Ogdensburg for at least some weeks, I think it best to submit the report at this time, and I accompany it with this brief statement, which is based not only upon what Mr. Fuller has told me, but upon my knowledge of the general situation and recollection of Ogdensburg, which I had the pleasure of visiting some years ago in connection with another water supply problem.

I am perfectly clear that you would best adopt the St. Lawrence River in place of maintaining the present supply. This is not because it will be cheaper, but because you can with much greater certainty get from the St. Lawrence a water supply that will be entirely satisfactory in quality. The added hardness of the St. Lawrence River is against the project. I have canvassed this matter carefully; but the objection is not a controlling one. The other advantages of the St. Lawrence supply more than offset it, and we recommend the St. Lawrence, notwithstanding the admitted greater hardness of the water.

I have looked over the financial aspects of the case on the figures which Mr. Fuller has secured from Mr. Lord. It seems that by close figuring your project can just about be financed on your present water rates. To do this will leave you a little cramped in the matter of extending the works and paying off your old bonds. Really the water income ought to be increased a little to leave you in strong and thoroughly satisfactory financial conditin. This might be done by getting the city to pay hydrant rental for a few years, or for such period as was necessary; or if this should not be practicable, some selected water rates might be raised to give ten per cent more income. I would raise fixture rates rather than meter rates, because the more meters you can get installed the better off you will be. At the present time the water revenue raised in Ogdensburg is 20 per cent. below the average, and it will not be necessary to raise the water rates even to the average to provide sufficient income so that considerable extensions can be made from revenue.

Mr. Fuller will go to Ogdensburg with the report and with this letter, and will take up with you personally all the matters in the report, and will endeavor to explain any matters that you are in doubt about, aud I hope and believe he will be able to make it all clear to you.

The project presented, while not the cheapest, is, I am sure, the best for you to adopt, and well worth all that it will cost.

Respectfully yours,

(Signed) ALLEN HAZEN.

New York
State Department of Health,
Albany.

(Copy) September 29, 1908.

Mr. H. A. Lord, Supt. Water Works, Ogdensburg, N. Y.:

Dear Sir—I beg to acknowledge receipt of your letter of September 28, 1908, enclosing copy of report submitted by Weston A. Fuller to your Board on the proposed filtration plant and other improvements for your water supply, and transmitting a request from your Board of Water Commissioners that this report be reviewed by our Engineering Division and such comments made thereon as may seem advisable, and to say that:—

I have accordingly had our Chief Engineer, Mr. Horton, review the report and the report of Mr. Fuller, and I enclose herewith a copy of his report to me. Mr. Horton's report reviews not only the proposition as worked out and recommended by Mr. Fuller, but also reviews the progress of this movement for a better supply which has been taken up by the Department co-operatively with you.

In accordance with Mr. Horton's recommendations, I beg to give you my full approval herewith of Mr. Fuller's report and express to you my interest and desire that everything be done by your Board and City Council to secure at as early a date as possible a new supply of filtered water from the St. Lawrence river as proposed and recommended in said report.

Very respectfully,
..(Signed) EUGENE H. PORTER,
Commissioner of Health.

..September 30, 1908.

Eugene H. Porter, M. D., State Commissioner of Health, Albany, N. Y.:

Dear Sir—In accordance with your instructions, and pursuant to the request of the Water Commissioners of Ogdensburg for your opinion and approval of the report of W. E. Fuller of the firm of Hazen & Whipple as to the best means of improving the quality of the water supply of that city, I beg to say that I have carefully reviewed the report of Mr. Fuller, and report herewith as follows:

As you are well aware, the State Department of Health has, with your initiative, taken a deep and active interest in the matter of improving the sanitary conditions in the city of Ogdensburg. During 1907 a special investigation and report of the conditions which existed at that time in the city was carried out by the Engineering Division under your direction, and the findings of the report thereon clearly showed that the high death rate which exists and has existed for the past twenty years was due to the impure quality of its water supply. This report was transmitted to the city at a special joint meeting of members of the City Government and the State Department of Health, at which time the question of correcting certain conditions, and especially of improving the quality of the public water supply, was urged upon the city.

This report and the recommendations therein was considered and acted upon by the Water Board with a promptness and spirit of co-operation that deserves commendation, for soon following was a request of the Water Board (through its Superintendent, H. A. Lord,) for the further services of the State Department of Health in the matter of its water supply. It was in response to this request that you directed me on January 9, 1908, to visit Ogdensburg, confer with the members of the Board of Health and Water Commissioners, and give what advice and assistance it was possible in this matter of improvement or filtration of their water supply.

With the Superintendent, Mr. Lord, I made a careful inspection within the city limits of the conditions and character of the Oswegatchie River and St. Lawrence River with a view to their adequate purification, and incidentally inspected and considered certain wells which it was thought might be

used as a source of supply. At a meeting with members of the Board of Health and Water, I discussed freely the general question of water purification, especially the methods of filtration, and comparing in a general way the relative merits of filtering the Oswegatchie and the St. Lawrence, and giving approximate estimates of cost of purification by the method of mechanical and of slow sand filtration.

I emphasized the impracticability of stating at that time without further information as to the chemical and biological quality of the two river waters, and a careful engineering study of the relative costs, which of the two propositions, to filter the Oswegatchie or the St. Lawrence, would prove the most satisfactory from a sanitary standpoint, or most practicable and economical from a financial standpoint. I finally emphasized the desirability and economy of securing the services of a competent sanitary engineer and having a thorough investigation of the entire problem in order to settle these questions definitely and accurately, and thus determine now, before any money is expended and before it is too late, which of these alternate propositions is the best.

The Board of Water Commissioners, acting again with promptness and foresight, secured at once the services of Hazen & Whipple, eminent consulting experts in this field of engineering, and the accompanying report of Mr. Weston E. Fuller of that firm is ample testimony of the course which has so far been co-operatively followed by the Water Board and this Department. This report while showing clearly the practicability of filtering satisfactorily and economically supplies taken from both rivers, and at costs which are reasonable and only slightly in excess of the approximate figures given them by me last winter, shows clearly that the filtration of the St. Lawrence River water will give a supply which is purer; one which will be attended with less trouble in operation; and, notwithstanding the slightly greater initial cost, one which in these and almost all other respects is the most desirable and profitable to develop.

I have reviewed most carefully those portions of the report which deal with the relative merits of the two different sources and the comparative costs. While there may be some slight and just difference in opinion as to the relative value of certain factors, they are not of sufficient importance to take issue with.

It is gratifying to learn that, while the purification of the St. Lawrence River water is somewhat higher than of the Oswegatchie in first cost, the excess of cost is smaller than it was thought it might be prior to the present investigation. Again, it is found that the hardness of the St. Lawrence River water, although some two or three times greater than the Oswegatchie, is nevertheless not a hard water, and compares favorably with most of the surface water supplies of the country where neither trouble nor complaint on the part of the citizens exists.

I believe, then, in view of the superior sanitary quality of a supply taken from the St. Lawrence River; the slight difference in estimated costs of developing the St. Lawrence and the Oswegatchie projects; the permanency of a filtered supply taken from the St. Lawrence River; the possible difficulties that might attend the operation of filtering Oswegatchie River water; and notwithstanding the relative but unimportant excess in hardness of the St. Lawrence River water, that it will be safer, ultimately more economical and otherwise more profitable for the city to develop a filtered supply taken from the St. Lawrence River.

I beg to recommend, therefore, that you give your approval of the accompanying report of Mr. W. E. Fuller, and in transmitting the same to the Board of Water Commissioners that you urge upon them the importance of securing this new supply at the earliest possible time.

Respectfully yours,
(Signed) THEODORE HORTON,
Chief Engineer.

Ogdensburg City Water Works,
January 7, 1909.

Mr. D. W. Mulligan, City Attorney, Ogdensburg, N. Y.:

Dear Sir:—At a meeting of the Board of Water Commissioners held Monday evening, Jan. 4th, a resolution was adopted directing me to obtain an opinion from you in writing, as to certain provisions of the bonding laws of the State of New York as follows:

FIRST. May a municipality of less than one hundred thousand inhabitants issue bonds for improvement of its water supply for a longer period than 20 years If yes, what is the time limit?

SECOND. May this municipality issue water bonds and arrange the payment of the principal sum in such manner that a considerable portion of the principal of the bonds shall remain outstanding and unpaid at the end of the bonds term, and may the residue of the principal be refunded and retired by bonds issued expressly for refunding purposes?

THIRD. May this municipality issue bonds for the improvement of its water supply, and pay the interest thereon, but defer payment on the principal for several years (until the present indebtedness is paid) provided the principal of the bonds and the interest thereon are paid in full within twenty years?

FOURTH. Are we required by law to pay (or place in a sinking fund) each year a stated per cent. of the principal sum of bonds issued for water supply improvement?

Yours respectfully,
(Signed) H. A. LORD,
Superintendent.

Ogdensburg, N. Y., January 13, 1909.

James M. Wells, Esq., Chairman Water Commissioners, City:

Dear Sir:—Replying to the inquiry of H. A. Lord, Superintendent, dated January 7th, 1909, and attached hereto, I wish to report that I have carefully examined such law as I could find in answer to the questions submitted, and my opinion is as follows:

A municipality of less than one hundred thousand inhabitants, whose indebtedness shall not exceed ten per cent. of the assessed valuation, may issue bonds for a longer period than twenty years, and there seems to be no limit upon the time such bonds shall run, except that in the case of where bonds are issued to take up old bonds that have become due, that new bonds shall be made payable not less than one or more than thirty years from their date.

In relation to the second question, I wish to reply that there seems to be no obstacle in the way of a municipality issuing water bonds and arranging the payment of the principal sum in such a manner that a considerable portion of the principal of the bonds shall remain outstanding and unpaid at the end of the bond term, and by a system of refunding may be retired by new bonds issued expressly for refunding purposes.

In answer to the third question, I should say that in case the indebtedness of the city did not exceed ten per cent. of the assessed valuation, the municipality could issue water bonds and pay the interest thereon but defer payment on the principal for several years.

In answer to the fourth question, it would seem from the decisions made in this State that where the total indebtedness of the city does not exceed ten per cent. of the assessed valuation, it is not necessary that a stated percentage of the principal sum of water bonds should be paid each year or placed in a sinking fund.

I can say as to the opinion expressed above that since the new State Constitution was adopted, the decisions of the courts upon the matters in question above are not numerous and there is some doubt among the judges of the lower court as to whether a water bond can be issued for longer than twenty years.

In the city of Rochester vs. Quintard, 136 N. Y. 225, the Court of Appeals takes up this question and the following is the language of Finch, Justice: "The appelant insists that a correct construction would make it read that in no case shall water bonds be issued running more than twenty years but that certainly contradicts the terms of the provision. The Constitution puts no prohibition upon cities having less than the specified population so far as city purposes are concerned."

In Sweet vs. city of Syracuse, 129, N. Y. 316, it was held that there was no restriction put upon cities having the requisite population, except where their debt has reached the maximum limit or has grown so near to it that the new debt proposed to be created would cross the fixed boundary and exceed the permitted amount. It would be extraordinary and indefensible construction to say that a water debt, which the fundamental law so favors and deems of such imperative necessity that it permits it to be contracted even after the safe and prudent limit of debt has been reached, should be hampered with restrictive provision when no other debt existed at all, there could be no more danger of injurious consequences in case of cities having less than the prescribed population.

This case was decided before the last amendment to the State Constitution and holds without doubt that in cities of the size of Ogdensburg water bonds may be issued for more than twenty years, and that that limitation in the Constitution does not apply. The interpretation of the amendment to the Constitution on this point is the subject of a difference of opinion in the Courts, and in Cahill vs. Logan, decided in 1904, 44 Misc. 367, Judge Herrick in rendering the opinion uses the following language: My own impression is that the twenty-year limitation in the Constitution applies to all bonds issued to provide a supply of water for a city, but that opinion is in apparent conflict with the opinion of the court in the case of Sweet vs. city of Syracuse, 129, N. Y. 316. Since that decision, the Constitution has been amended and whether the provisions requiring the terms of such bonds not to exceed twenty years applies to all water bonds or not, it seems to me perfectly clear that it applies to the proposed issue of bonds that will, when added to the existing indebtedness, cause such indebtedness to exceed ten per cent. of the assessed valuation of the real estate of the city.

While Judge Herrick does not squarely pass upon the question, he does decide that where the new bonds would cause the indebtedness of the city to exceed ten per cent. of the assessed valuation, in that case the bonds cannot be for more than twenty years, and inversely he decides that in the case of a city whose indebtedness is well below ten per cent., the bonds could be issued for a longer term than twenty years.

In the case of the city of Rome vs. Whitstone Water Works Co., 113 A. D. 549, decided in May, 1906, under the new Constitution, the City of Rome in order to obtain an additional supply of water for public use sought by an act of the Legislature to obtain by condemnation certain real estate owned by the Whitstone Water Works Co. In one section of the Act, provision was made for the issue of bonds by the Common Council for the purpose of raising money to carry out the proposed plan, but through an oversight, no provision was made for a sinking fund to pay the bonds. It was, therefore, claimed by the defendant that in the absence of such a provision, the city, under requirements of section 10 of article 8 of the Constitution, has no right to issue the bonds, and Judge Merwin, referee, decided that the Constitutional requirement as to a sinking fund does not apply to a case where the ten per cent. limit referred to in the Constitution has not been reached.

While this case has never gone to the Court of Appeals it would seem from this that, even though a sinking fund or a yearly payment of a part of the principal was unprovided for, the bonds would be within the Constitution as the issuing of bonds would not cause the indebtedness of the city to reach the ten per cent. of the assessed valuation.

By section 7 of the General Municipal Law of the State, it is provided that the bonded indebtedness of a municipal corporation, including interest due or unpaid or any part thereof, may be paid up or retired by the issue of the new substituting bonds for like amounts by the Council or officers

having in charge the payment of such bonds. Such new bonds shall only be issued when the existing bonds can be retired by the substitution of the new bonds therefor or can be paid up by money realized by the sale of such new bonds.

It would seem from this that the bonds might remain unpaid at the end of the bond term and be taken up by this system of refunding or issuing new bonds to take their place.

In the city of Poughkeepsie vs. Quintard, 19 N. Y. S. 944, it was held that the right to exchange a new bond of the city for an old one maturing is given plainly by the law and the right to pay old ones with the proceeds of the new is also confirmed. In that case the city issued bonds, the proceeds of the sale of which were to be applied to the payment of water bonds maturing the same year and it was found that this manner of payment did not create a new debt or obligation on the city.

In concluding, it is my opinion that this city can issue water bonds for any period they desire and are not restricted to a term of twenty years, but in case they issue bonds to take up old bonds becoming due, then the renewal bonds must be for a period not longer than thirty years. I am,

Very respectfully yours,

D. W. MULLIGAN,
City Attorney.

REPORT

On the PROPOSED 30-INCH FORCE MAIN, of W. C. HAWLEY, C. E., to the BOARD OF WATER COMMISSIONERS of ATLANTIC CITY, N. J.

With the SUPPLEMENTARY REPORT of the CONSULTING ENGINEER, MR. EMIL KUICHLING, C. E.

The Yuba Electric Power Company's Pipe, showing Curve.

REPORT

ON THE PROPOSED 30-INCH FORCE MAIN,

OF

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TO THE

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ATLANTIC CITY, N. J.,

WITH THE

SUPPLEMENTARY REPORT OF THE
CONSULTING ENGINEER,

MR. EMIL KUICHLING, C. E.

REPORT OF SUPERINTENDENT.

ATLANTIC CITY, N. J., August 24, 1900.

To the Board of Water Commissioners:

GENTLEMEN:—In compliance with the instructions of your honorable body, I respectfully present the following report as the result of a careful investigation of the various materials and methods of construction available for constructing a 30-inch force main from the Absecon Pumping Station to this city, as provided for by the ordinance passed by City Council, May 28th, 1900, and approved by the Mayor June 1st., 1900.

There are but three materials of which it would be possible to construct the force main, viz:

1st. Cast iron pipe.
2d. Riveted steel pipe.
3d. Wooden stave pipe.

I will consider these separately.

CAST IRON.

The following is an estimate of the cost of constructing a 30-inch cast iron force main:

4,000 gr. tons Cast Iron 30-inch pipe @ $27.00	$108,000.00 ~~$18,000.00~~
Valves and bolts for connections,	15,357.93
Special castings,	3,500.00
Beach Thoroughfare crossings, including material and labor,	13,500.00
Venturi Meter,	2,000.00
Connecting to pumping station and force mains,	1.160.00
Connecting to distribution system, material and labor,	12,500.00

Gate Houses,	3,000.00
Unloading and hauling,	3,000.00
Laying 26,700 feet 30-inch cast iron pipe, @ $.80,	21,360.00
Extra for creek crossings,	2,500.00
	$185,877.93
Engineering, inspecting and contingencies, 7½ per cent.,	13,940.84
	$199,818.77

The plan upon which this estimate is based, provides for a 30-inch cast iron main with two lines, each 20 inches in diameter, under Beach Thoroughfare, the main entering the city along North Mississippi Avenue, connecting with the stand pipe at Ohio and Baltic Avenues by a 20-inch main on Baltic Avenue, and continuing on Mississippi Avenue 24-inch to Arctic Avenue, 20-inch to Atlantic Avenue, and 16-inch to the Beach main at Columbia Avenue. The Beach Thoroughfare crossing will be made by two lines of 20-inch ball joint pipe laid on saddles supported on creosoted piles.

The existing 12-inch and 20-inch force mains are cast iron with the usual lead joint every twelve feet. As these mains are laid parallel with and close to a railroad track for about four miles on the meadows, the jar of the trains is constantly straining and damaging the non-elastic lead joints, necessitating daily inspection and very frequent repairs. With a 30-inch pipe the weight, 4,000 to 4,200 pounds per length of twelve feet, would be so great as to cause more or less settlement and the consequent damage to the main.

Another matter to be considered in connection with a cast iron pipe, is the deterioration of the metal. Where the present mains are bedded in the salt mud of the meadows, it is found in many places that a chemical change has taken place in the metal to a depth of one-eighth of an inch, and that that part

of it can be cut like chalk. This action is probably caused by the galvanic action of the iron, the free carbon of the metal and the salt water, in which we have all the elements of an electric battery.

We do not know the rate of this deterioration, nor whether it is increasing or diminishing. The ordinary coal tar coating which is put on cast iron pipe affords little protection, and hence the estimate includes cost of first-class asphalt coating.

In making this estimate I have planned on laying the pipe so as to barely cover it with a layer of sod. It will be connected at various places with the existing force mains and provided with a sufficient number of valves so that in case of break or serious leak, it will only be necessary to close out one section of the main for repairs.

RIVETED STEEL PIPE.

This has been used for mains in several places, and is cheaper in sizes over thirty inches in diameter, than cast iron. There is probably very little difference in cost, however, between a 30-inch main of cast iron and a 30-inch steel main when the difference in carrying capacity is considered. Owing to the certainty of damage to the coating of a steel pipe in laying, the absolute impossibility of efficient repairing and inspection in a pipe only thirty inches in diameter, the rapid corrosion which will follow any exposure of the metal to the action of the salt mud of the meadows, and also to the fact that the carrying capacity of a 30-inch steel pipe after a few years service is about fifteen per cent. less than that of a cast iron pipe of the same size, I do not think it worth while to consider it for the proposed force main.

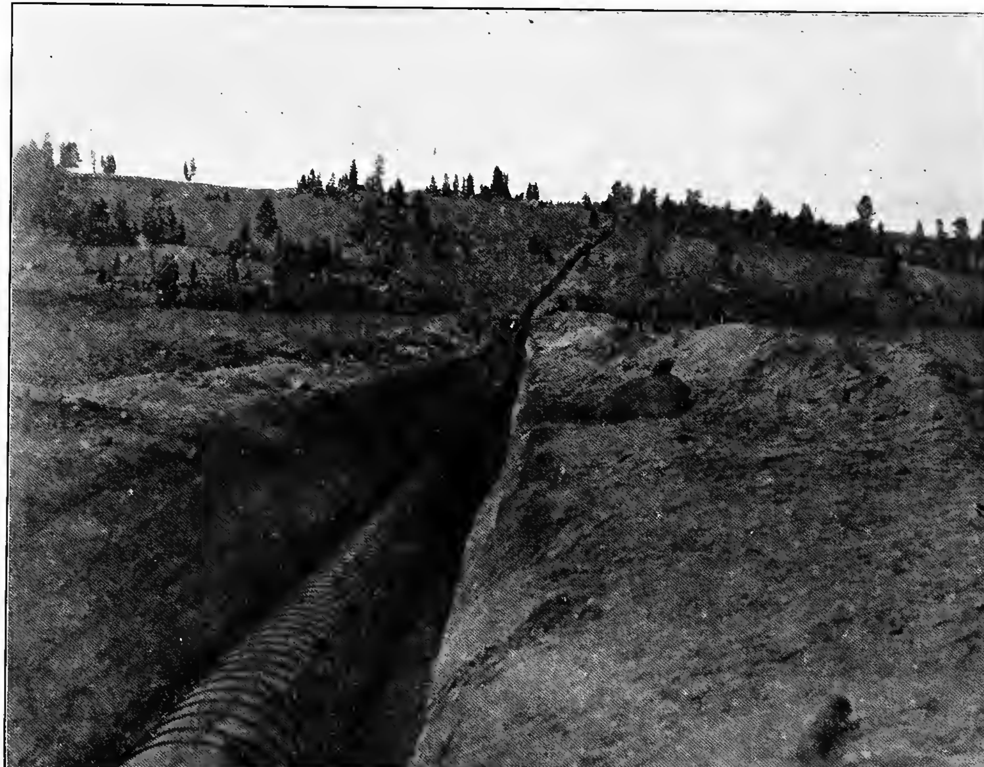
WOODEN STAVE PIPE.

In the West within the past twenty-five years, a pipe, built in place, of wooden staves banded with

round or oval steel or wrought iron bands, has been extensively used, and were intelligently constructed, with excellent results. Denver, Col.; Butte, Mont.; Astoria, Or.; San Francisco, Cal.; and many other cities and villages are supplied with water through stave pipes, and many power plants and mines also have it in use. A similar pipe has been used in the East for mill flumes for from 25 to 50 years. A pipe is now in use in Manchester, N. H., which was built in 1872. It is six feet in diameter, about 600 feet long, and is under from 12 to 40 feet head. It has never leaked and has needed no repairs.

At Wicopee, Dutchess Co., N. Y., on Fishkill Creek, there was, in 1893, a 30-inch stave pipe which had been in use for power purposes for 45 years. It was reported at that time as in good condition and good for many more years of service. At Portsmouth, N. H., in 1797, bored pine logs were laid for water pipe, having five inches internal diameter. The last of these was taken out after having been in service for about 75 years, and the wood was still sound. There are numerous other cases which could be cited.

With Commissioners Reiley and Booye, and Councilman Long, Chairman of the Committee of Protection of Property and Improvement of City Council, I recently made a tour of inspection in the West, paying particular attention to the materials and methods of construction of wooden stave pipe, and to the condition of pipes which had been in service for some years. At Butte, Mont., there were ten miles of 24-inch stave pipe which had been in service nine years, and over twenty miles of 24-inch and 26-inch stave pipe are now being constructed. We saw the 26-inch stave pipe in process of construction Redwood staves were being used, banded with $\frac{7}{16}$-inch steel bands, which were coated with Mineral Rubber. We noted particularly the speed with which the pipe was built, the strength and excellent



Line of 26-inch Wooden Stave Pipe, Butte, Montana.

quality of the finished pipe, and we were greatly impressed with the ease and rapidity with which the pipe can be repaired. We were extended every facility for examining the work by Mr. Payne, the Engineer in charge of the work, and we also visited the old line of 24-inch stave pipe. We found the staves of this pipe as good as new, and the bands, saddles, and nuts were also in excellent condition, after nine years of continuous use.

At Seattle, Wash., the city is now constructing about twenty-two miles of 42-inch to 50-inch pipe. We saw the pipe being built. Washington Fir is being used for staves, and ½-inch steel bands are being used, the latter coated by being dipped in hot asphalt. Photographs were taken of both the Butte and the Seattle pipe. At Seattle we were accorded every courtesy by Messrs. C. P. Allen & Son of the contracting firm, and City Engineer R. H. Thomson. Among other things we were shown a 48-inch wooden stave pipe used for a sewer under most adverse conditions, being laid so that it is nearly covered at high tide, and thus exposed to the action of drift and ice, and entirely exposed to the air at low tide. To make these conditions worse, the sewer ordinarily flows from one-half to two-thirds full. This sewer was built seven years ago, and the fir staves are in excellent condition. The bands are only very slightly rusted, not enough to be damaged at all, though only dipped in hot asphalt.

At San Francisco we met Mr. D. C. Henny, C. E., Manager and Engineer of the Excelsior Wooden Pipe Co., from whom we obtained a number of photographs and much information on the subject of stave pipe, especially where laid in salt marsh, as Mr. Henny's Company has laid several such pipes. He stated that when those pipes had been examined, after being in service some years, they were in good condition. Mr. Henny mentioned

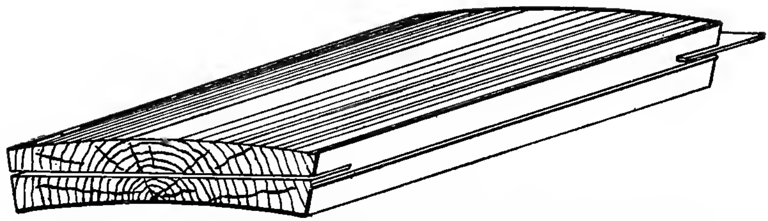
one case where a steel riveted pipe laid in salt marsh had given out in a short time, and been replaced by wooden stave pipe with success. Near Floriston, Cal., we saw from the train a stave pipe, nine feet in diameter, about one-half a mile in length.

At Denver, while we were unable to see any of the pipe, the city has over 50 miles of stave pipe which is stated to be in good condition after eleven years of constant and satisfactory service.

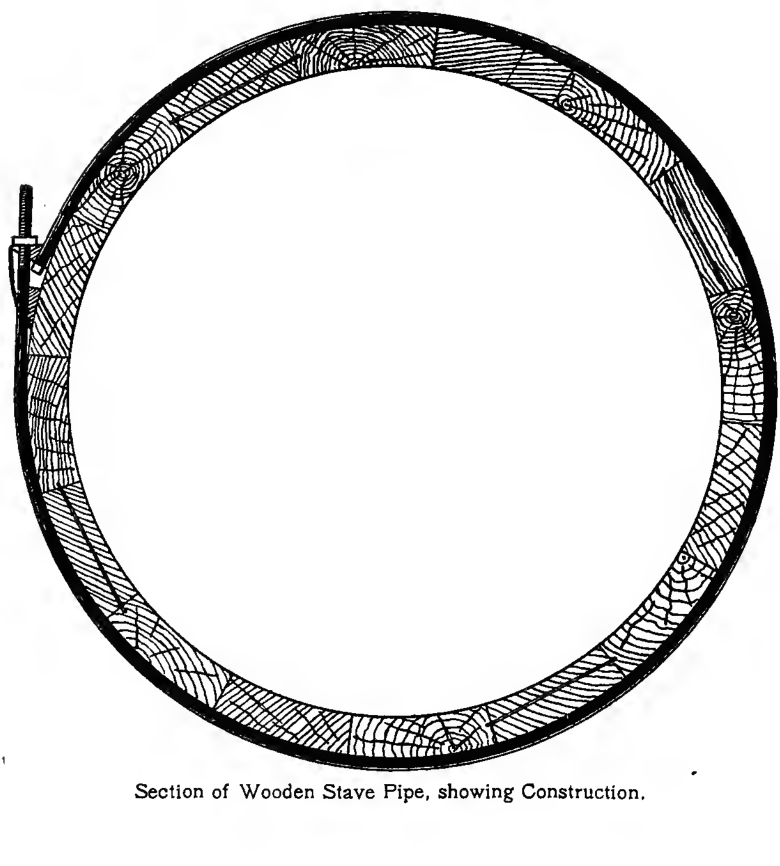
We visited Mr. C. P. Allen's office in Denver, and saw many samples of staves, bands, saddles, etc., and photographs of pipe lines.

While on the trip we secured such information as to cost of materials and construction as we were able, and the following is an estimate of the cost of a 30-inch wooden stave force main calculated on the same basis as the estimate of the 30-inch cast iron main. Under Beach Thoroughfare I have figured on two lines of 20-inch cast iron ball joint pipe laid on saddles supported on creosoted piles:

26,700 feet 30-inch Wooden Stave Pipe, at $3.55,	$ 94,785.00
Valves and bolts for connections,	15,357.93
Special castings,	3,550.73
Beach Thoroughfare crossing, including materials and labor,	13,500.00
Venturi Meter,	2,000.00
Cast iron pipe at pumping station, and laying,	550.00
Connecting to force mains,	1,000.00
Gate Houses,	3,000.00
Materials and connections to Distributing System,	12,500.00
Extra for crossing Adam's Ditch and Jonathan's Thoroughfare,	1,700.00
Unloading and hauling Gate Valves, etc.,	500,00
	$148,443.66
Engineering inspection and contingencies, 10 per cent.	14,844.37
	$163,288.03



Sketch showing Tongue and Slot in End of Stave for making Brett Joint.



Section of Wooden Stave Pipe, showing Construction.

You will note that compared with the cast iron pipe, the wooden stave pipe will cost $36,530.74 less.

A comparison of the qualities of the wooden stave pipe with those of cast iron for our conditions, are almost wholly in favor of the former: viz:

(*a*) The wooden stave pipe as built is continuous, while the cast iron has a non-elastic lead joint at least every 12 feet. Laid as our mains are, close to railroad tracks, this is an important matter as already pointed out. This has been demonstrated by our experience with the existing force mains.

(*b*) The durability is the only point where cast iron might have the advantage over wooden stave pipe, and as already shown, even this is questionable under the conditions on the meadows. The staves are made of a thickness that insures their always being kept saturated by the water under pressure within, and it is a well known fact that wood which is kept wet and free from contact with air, will never rot. Hence it is the life of the bands which will determine the life of the pipe. To coat and protect these bands with some suitable preservative, is but a matter of careful, painstaking, honest inspection, and will be far more easily accomplished than the coating of heavy cast iron pipe. The stave pipe is designed with a safety factor of 4-½ or 5 and should a few of the bands be destroyed, it would be an easy and inexpensive matter to replace them.

(*c*) The wooden stave pipe is much less liable to breaks or leakage than a cast iron pipe. It is so designed that it cannot burst. Before a pressure sufficient to burst the bands could be applied, the staves would be forced back against the bands, forcing the bands into the staves and opening the joints between the edges of the staves, thus causing leakage, which would relieve the extra pressure.

(*d*) The wooden stave pipe can be repaired with far greater ease than cast iron. If a band has

given out, it is but a few minutes work to replace it. If it is a damaged stave or staves, it is only neccessary to loosen a few bands, slip them back on the pipe, pry out and cut off the stave or staves to be replaced, cut new stave or staves to proper length, slot the new ends and put in the tongues, buckle staves into place and replace bands. This ease of repair is a very important matter in our case. Anyone who is familiar with the mud and other conditions on the meadows will realize at once the difficulty of repairing a 30-inch cast iron pipe which involves handling lengths of pipe weighing 4,000 to 4,200 pounds, as well as the further difficulty of using melted lead for making joints. Even with the present 20-inch main, in making repairs it is frequently impossible to run a joint with melted lead, and the only thing that can be done is to pound in cold lead which does not make a good joint.

(*e*) The difference in weight is, under the conditions on the meadows, very much in favor of the wooden stave pipe. As before stated, there would be difficulty and expense in preventing serious settlement of a 30-inch cast iron pipe in the meadow mud.

(*f*) The carrying capacity of wooden stave pipe is considerably greater than that of cast iron pipe, on account of the smoothness of the inner surface of the pipe, and it does not decrease as does that of cast iron pipe. Experiments show that for 30-inch pipes when new, the wooden stave pipe will carry 10 per cent. more than cast iron ; after a few years when the cast iron pipe has become tuberculated, the difference increases to about 40 per cent.

For the reasons above enumerated, I am lead to recommend the use of wooden stave pipe for the proposed force main, as the most suitable and reliable for the purpose, as well as the cheapest in first cost, and also in cost of maintenance. This recommendation is endorsed by your Consulting Engineer,

Mr. Emil Kuichling, member of the American Society of Civil Engineers.

In connection with this matter I wish to call your attention to the following plan which was suggested to me by Mr. D. C. Henny, while in conversation with him in his office in San Francisco.

When the present plant at the Absecon pumping station was constructed, Atlantic City had a population of about 13,000 people. When the city purchased the plant in August 1895, the population was about 18,000. To-day it is about 28,000, and the summer crowd, which is what tests the capacity of the works, has increased in even a greater ratio. With the prospects of a continued growth, and the inability to furnish an adequate supply which we are now experiencing, it becomes evident that considerable improvements and additions must be made in the near future at the pumping stations.

The first thing to be done is to develop and increase the underground supply.

The existing suction well is not of sufficient depth and is too far from the basins. The old plank flume has about rotted out and must soon be replaced or abandoned. There is no room in the present pumping station for any additional pumps or boilers. The suction lift of the pumps, as now set, is greater than it should be. It will, hence, be but a short time before it will be necessary to make radical changes to the plant. A new suction well will have to be sunk nearer to the basins and the timber flume replaced by a pipe of proper size. When this is done, the present machinery should be moved into a new and larger pumping station, and two new high duty pumps, one 5,000,000, and one 3,000,000 gallons capacity in 24 hours, with the necessary boilers, be added. The present 5,000,000 high duty pump should have new and larger plunger rings and plungers.

In developing the underground supply, it will probably be necessary to use centrifugal or low lift reciprocating pumps to lift the water from a greater depth than the pressure pumps will reach.

It will make very little difference in cost of operation whether the water is merely lifted to the pumps as they now stand, or *whether it is lifted to a sufficient height to cause it to flow by gravity across the meadows to a pumping station in the city.* A wooden stave pipe to carry the water thus under very low pressure would however cost materially less than a main such as I have figured upon to carry the water under 75 to 50 pounds pressure, and there would be this *very great advantage*, that with the plant constructed and operated in this way, nearly *all danger of leaks or failure of the force mains on the meadows would be avoided.*

As there are frequently times during storms or high tides when the meadows are entirely inaccessible in case repairs should be needed, this is a consideration to which I would urgently call your attention, especially in view of the danger from fire in a city containing so many frame buildings, in case of any failure of the water supply

In preparing the estimate which follows, I have assumed that it will cost no more to develop and increase the underground supply at the Absecon pumping station, whether the pumps are there or in the city. The city owns enough ground on North Kentucky Avenue in this city, where the present Consumers Pumping Station is located, for the construction of a new pumping station, and both plants could be installed in one station and operated by one set of men. If, therefore, we do not now consider the cost of the new machinery, which will be the same in either location of the pumping station, the only increased cost due to change of pumping station to Atlantic City will be the increased length of force main, the tanks

Laying 26-inch Wooden Stave Pipe, at Butte, Montana.

needed for storage, and the change in distribution system necessary for making connection to it. Part of the latter will be necessary in two or three years, whether the change in location of pumping station is made or not, and hence I have shown the cost of that separate. The estimate contemplates a force main of a maximum capacity of 10,000 000 gallons in 24 hours, under a pressure of 27 pounds at the main land, delivering into a tank at elevation 12 at North Kentucky Avenue. From the point on this side of Beach Thoroughfare, where Hummock Avenue produced, intersects the present force mains, I have figured on a 36-inch wooden stave pipe along Hummock Avenue to Kentucky Avenue, thence on Kentucky Avenue to the pumping station. The necessary new mains to connect with the distribution mains would be a 20-inch line on Mediterranean Avenue from Kentucky to Ohio Avenue, on Ohio Avenue from Mediterranean Avenue to Baltic Avenue, connecting there with the stand pipe thence on Baltic Avenue to Missouri Avenue connecting with the present 20-inch force main there There will also be needed a main east from Kentucky Avenue on Mediterranean Avenue with cross mains to Pacific Avenue on Virginia Avenue and Connecticut Avenue. The cost of this has been added to the estimate under the item "Extension of Distribution System."

The following is the estimate of the cost of a wooden stave pipe built as proposed in this plan:

25,575 feet of 30-inch Wooden Stave Pipe, at $2.40 per foot,	$61,380.00
3,300 feet of 36-inch Wooden Stave Pipe at $3.50 per foot,	11,550.00
Valves and bolts for connections,	14.857.93
Special castings,	3,550.73
Beach Thoroughfare Crossings, including material and labor,	13,500.00
Venturi Meter,	2,000.00

Cast iron pipe at pumping station and laying,	550.00
Connecting to force mains,	1,000.00
Gate Houses,	3,000.00
Extra for crossing Adams Ditch and Johnathan's Thoroughfare,	1,700.00
Unloading and Hauling Gate Valves etc.,	500.00
Connecting the Distribution System,	7,450.00
	$121,038.66
Engineering, Inspection and Contingencies, 10 per cent.	12,103.87
	$133,142.53
Extension of Distribution System,	9,400.75
	$142,543.28

You will note that this shows a saving of $20, 744 75 compared with the high pressure wooden stave pipe, and $57,275.49 compared with the cast iron main.

Owing to the limited time which I have had in which to consider this matter, I cannot give the exact cost of the proposed changes, but the following is an approximate estimate:

Probable cost of developing underground supply at Absecon Pumping Station, including new machinery and alterations to pumping station, from $15,000 to	$35,000.00
New pumping station on North Kentucky Avenue, including moving and resetting pumps and boilers, including new boiler,	27,000.00
Two steel tanks, 100 feet in diameter and 15 feet high, with foundations and pipes, or masonry basins of equal capacity,	26,000.00
Changes to present Consumers Pumping Station,	2,000.00
	$90,000.00

If these changes are made, the total expenditure will be about $230,000 to $235,000. The reduced liability of breaks and leakage in the force mains on the meadows, and the resulting security against a water famine, is worth many times, to the

City of Atlantic City, the $30,000 or $35,000 which it will cost over the original estimated cost of the force main. It is probable, however, that the saving in cost of operation of the proposed plant, compared with the present plant, will more than offset this additional cost. I therefore recommend the building of a low pressure wooden stave pipe, with the development of the underground water supply at the Absecon Pumping Station, the change in location of the pumping station, and the necessary changes in the distribution system, as outlined above.

Very respectfully submitted,

W. C. HAWLEY,

Superintendent.

REPORT OF CONSULTING ENGINEER

ATLANTIC CITY, N. J. September 3, 1900.

To the Honorable, The Board of Water Commissioners of Atlantic City, N. J.:

GENTLEMEN:—In accordance with your request of the 31st ult., to present to your Board and the Committee on Protection of Property and Improvement of City Council a written review of the Report made on the 24th ult., by Mr W. C. Hawley. C. E., Superintendent of the Atlantic City Water Works, in relation to the proposed new water conduit from Absecon Pumping Station to the pumping station at the corner of Kentucky and Mediterranean Avenues, the undersigned begs leave to submit the following:

SIZE AND QUALITY OF CONDUIT PIPE.

It appears that the diameter of the proposed conduit has been fixed by the Ordinance of May 28th, 1900, at 30-inch, and that the main question now is about the material of which it shall be constructed. As stated in the report, the pipe is to be subjected to more or less internal water pressure, and hence the choice of material is restricted to cast iron, riveted steel plate, and wooden staves held together by steel bands, all of which are well adapted to the purpose under ordinary conditions. In the present case however, the conditions are somewhat unusual, inasmuch as nearly the entire length of the conduit will be exposed on the outside to the action of sea water, and that special care must therefore be taken to protect

the metal from corrosion; also that, for the greater part of the distance of five and six-tenths miles between the two pumping stations, the pipe will be located on the salt marsh in close proximity to one or two lines of railway, the heavy traffic on which produces severe tremors or vibrations in the adjoining soft ground.

These vibrations tend to loosen the lead joints of cast iron pipes, and to promote leakage therefrom which will ultimately cause settlements and breakage of the pipe itself; and the use of flange joints in such pipes is impracticable on account of their rigidity. Furthermore, the present 12-inch and 20-inch cast iron pipes across the marsh exhibit great deterioration after only a few years by external corrosion, as pointed out in Mr. Hawley's report; hence it becomes expedient to provide for the most efficient protective coating in the proposed new work. The application of such a coating, however, will obviously increase the price of the pipe somewhat, and this brings its cost to the figures named in said report. Excluding the trench and the timber foundations that may be required for the heavy pipe in many soft places in the marsh, the cost of the 30-inch cast iron pipe in place may be taken at $4.60 per lineal foot.

Riveted steel pipe, made of plates ¼ inch thick and with either riveted or flanged joints, is much better adapted to laying in the soft marshy soil than the cast iron pipe, and affords much more security against damage from the tremors or vibrations in the vicinity of the railroads. It is, however, open to the serious objection of very rapid corrosion when exposed to salt water, and hence the utmost care must be taken in preparing and applying the protective coating. From an extensive experience with such pipe, the undersigned deems it expedient to use plates not less than ¼ inch thick, and to require

the application of at least two thick bituminous coatings on the outside, the second coating to be further guarded against damage during transportation and handling by a wrapping of burlap. All abrasions or injuries to the exterior surface must be scrupulously repaired before the pipe is covered in the trench, otherwise active rusting by the salt water will make the life of the conduit comparatively short.

There are, however, so many chances of injury to the protective coating, and the care needed during the progress of the work to repair such damage is so great, as to render it practically impossible to secure a perfectly continuous protective coating, especially on the lower part of the pipe which is obviously the most difficult of access; hence, it is very probable that in spite of all the vigilance that may be exercised in the supervision of the work, more or less corrosion and consequent leakage will soon develop in the conduit. This may be expected to continue indefinitely, as each exposure for subsequent repairs affords an opportunity to create new abrasions of the coating, and hence the cost of maintenance will probably attain a considerable magnitude. The first cost of such a 30-inch riveted steel pipe, laid in place, but not including the trenching and back-filling, may be estimated at $3.60 per lineal foot.

Wooden stave pipe, made of sound and clear fir, redwood, or southern pine lumber, and held together by a sufficient number of steel bands to resist with ample safety, both the internal water pressure and the expansive force due to the swelling of the wood from the absorption of moisture, is also well adapted to the purpose uuder consideration. Many of the advantages and details of constructing such conduits have been set forth so clearly in Mr. Hawley's report that little further need be added thereto here. The only addition which appears to be required is a reference to the protection of the wood against the

attacks of the teredo and other marine animals or organisms. On this point it may be mentioned that a thorough examination of a large number of telegraph and telpehone poles which have been set for many years in the salt meadow, has demonstrated that at and below the surface of the ground this wood is still perfectly sound and entirely free from such attacks; also, that an inquiry into the habits of the teredo and limnoria, which are the most active of the marine boring animals, has disclosed the fact that these creatures cannot live in muddy or stagnant water, and hence never penetrate into the soil of such marshes. Furthermore, as the wood of the pipe is constantly saturated with fresh water and is kept from exposure to the weather by a thick covering of meadow sod, its great durability may fairly be regarded as definitely established.

The only question about the life of the wooden conduit is that which relates to the durability of the steel bands which hold the staves together. On this point it may be said that all which can be adduced in favor of protective coatings for steel plate and cast iron, applies with even greater force to the protection of the bands or hoops, as it is much easier to secure proper inspection and coating of a small rod than of a larger surface. Every band can be carefully examined before it is put in place, and can even be immersed in a bath of the preservative mixture immediately before it is applied to the pipe, so as to insure a perfectly continuous coating. The pipe also possesses considerable flexibility, which enables it to be built on blocking at a covenient distance above the bottom of the trench, thereby affording easy access to the lower side for recoating or repainting all portions of the bands, whereupon the blocks are finally removed and the pipe is lowered into place. No other excuse than gross negligence can be offered by an inspector if good coating workmanship is not

secured; and hence if reasonably intelligent and conscientious men are employed as inspectors, there will be a far greater probability of securing a durable conduit in this case than with either cast iron or riveted steel.

With respect to the cost of a 30-inch wooden stave conduit, it is proper to remark that the estimates of the undersigned are somewhat less than the figures given in Mr. Hawley's report.* Allowing for a reasonable margin of profit, similar to that which was used in the estimates for the cast iron and riveted steel pipes, the prices which are here considered fair for the work, exclusive of the trenching and back-filling, are $3.15 per lineal foot, for such a wooden pipe adapted to withstanding an average internal water pressure of 69 pounds per square inch, and $2.05 per lineal foot for one to withstand an average pressure of only 13 pounds per square inch. The difference in these prices is mainly due to the increased number of bands per lineal foot required to resist the higher pressure, and the two pressures mentioned relate respectively to the original plan of pumping at the Absecon station directly into the city standpipes, and to the modified plan, proposed by Mr. Hawley, of delivering the water from said station at a height of only about 12 feet above the surface of the ground at the City Pumping Station, and then repumping it to the required height into the standpipe.

It may also be added, that in view of the various uncertainties which affect the strength and durability of both the cast iron and the riveted steel conduit in this case, the undersigned does not deem it expedient to make any material reduction in the thickness or weight of the metal for the pipe which is subjected to the lighter pressure. For the comparison of cost with the light pressure wooden conduit, the above

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* To avoid confusion, the estimates given in Mr. Hawley's report as here printed have been revised to correspond to the prices given by Mr. Kuichling.

named estimates for the cast iron and riveted steel pipes will accordingly be retained. It should furthermore be noted that the items for valves, valve houses, special castings, water measuring device, Beach Thoroughfare crossing, extra work at Small Creek Crossings, connections with pumping stations and existing force mains, and connections and extensions of the distributing system, are all practically the same in amount for each kind of conduit in Mr. Hawley's estimates, as will obviously be the case, hence the difference in the cost of the entire work is determined almost wholly by the difference in the cost of the 30-inch pipes as given above, it being remembered that the required length of such pipe is approximately 26,700 feet.

We thus find for the cost of said pipe alone, exclusive of the trenching and back-filling, the following amounts:

26,700 lineal feet 30-inch cast iron pipe laid in place, ...	$4.60	$122.820
26,700 lineal feet 30-inch riveted steel pipe laid in place, ...	3.60	96.120
26,700 lineal feet 30-inch low pressure wooden stave pipe, ...	2.05	54.735
26,700 lineal feet 30-inch high pressure wooden stave pipe, ...	3.15	84.105

From these figures it is seen that the cast iron pipe is the most expensive, and that in comparison therewith, the wooden stave pipe will produce a saving of from $68,085 to $38.715, according as the low or high pressure conduit plan is adopted. In comparison with riveted steel pipe, on the other hand, the use of the wooden stave pipe will result in a saving of respectively $41.385 and $12.015. It is accordingly evident that the wooden stave pipe is by far the most economical material for this conduit, and there is every reason to believe that in respect to

both serviceability and durability, it will prove superior to either of the other materials. The undersigned therefore agrees fully with Mr. Hawley in this respect.

As to the size of the proposed new conduit, it may be remarked that the diameter of 30 inches is adapted to the most economical delivery by steam pumping of a volume of about 10,000.000 gallons of water at a uniform rate during 24 hours While this quantity may not be required at the present time, yet judging from the rapid rate of increase of the summer population, not many years will elapse before it will be needed, and hence the selection of size has been a wise and judicious one.

HIGH OR LOW PRESSURE CONDUIT.

In the choice between the high and low pressure conduits, a variety of conditions must be taken into consideration. At its best, the long conduit over the salt marsh, and for the greater part of its length in close proximity to lines of railway with a very heavy traffic, and also liable to be more or less deeply covered by sea water several times per year whereby repairs will necessarilly be delayed, cannot be regarded otherwise than as a relatively insecure structure, which should be subjected to as little internal stress and shock as possible. From this point of view the low pressure conduit must be given the preference. On the other hand, with a high pressure conduit and an abundance of excellent water obtained at Absecon, the pumping station in the city might be abandoned and an appreciable saving in the annual operating expenses might thereby follow.

With wooden pipe the difference in cost between the high and low pressure conduit is $29,370 according to the foregoing figures, and at four per cent. interest this sum will produce annually about $1,175. In contrast thereto must be placed the expense of

maintaining the attendants at the low lift pumping station at Absecon, since the expenses of the high lift station, and the aggregate coal consumption, will remain practically the same in either case. This expense will be about $3,375 per year, as both the power developed and the necessary number of men are relatively small; hence the difference in annual operating expenses will be about $2,200, or in other words, it will cost ab ut $2,200 per year more to maintain the two pumping stations with the low pressure conduit, than a single pumping station at Absecon with a high pressure conduit. It should also be remarked that to this sum should be added the annual interest and depreciation on the cost of the low lift pumping plant; but as most of the machinery needed for the purpose can doubtless be adapted without much additional cost from that which is already on hand at Absecon, it will hardly be fair to make said sum much larger than $2,500.

The question thus presents itself in the following form:—Is it worth $2,500 per year to have the greater security from accident to the long conduit which the low pressure plan provides? In view of what has already been said on the subject, and the further fact that so many of the buildings in the city are of wood and therefore inflammable, it seems to the undersigned that it would be eminently prudent to reduce the fire risk as much as possible by making the conduit as safe as possible, and this can best be accomplished by adopting the low pressure plan. The additional annual expense is not large, and will doubtless be more than compensated by a reduction in the insurance rates if the case is properly presented to the underwriters; and even if such a reduction is not granted, the knowledge that greater dependence can be placed on the water supply which comes from the mainland cannot fail to be of far more value than its additional cost to the property owners of a city

whose continued prosperity is so closely allied to means for preserving the safety, health and comfort of the visiting public. The undersigned has therefore no hesitation in recommending the adoption of the low pressure conduit.

Aside from the foregoing considerations, however, there are other reasons for adopting this plan. One of these is that there is a strong demand for a purely artesian water supply on the part of many citizens, which has resulted in the continued maintenance of the city station plant at relatively large cost. Now, with the proposed new conduit, the provision of a large additional quantity of water is directly associated, and as will be pointed out below, there is a good probability that an ample volume of such artesian water can be obtained near the Absecon station. Should the search for such water be successful, there will then be no reason for the further independent maintenance of the city station plant, and the supply now obtained at this point may either be treated as a reserve, or it can be operated without expense for attendance by the same set of men who will operate the high pressure station. Another reason is that it will sooner or later result in the provision of a large storage of water within the city for use in case of accident to the standpipe. By the first, there can be no reduction in annual operating expenses; and by the second, a greater safety against a shortage of water will be secured. An ample reserve supply of potable water is of enormous value to every large community, and it is obvious that the nearer such reserve is to the consumers, the better, especially if there is any doubt as to the stability of the conduit. Furthermore, if adequate storage capacity is provided at the City Pumping Station, it will be possible to reduce the expenses for attendance at the low pressure station by employing a single set of men for about nine

months of the year, and two sets during the summer. A saving of at least $1.000 per year can thus be effected which represents the interest at 4 per cent. on a capital of $25.000; and this capital can accordingly be expended in securing storage without adding to the previous annual charges.

COST OF RESERVOIR.

With respect to the quantity of water to be stored at the City Pumping Station, it may be said that the same should be at least equal to one day's consumption during the greater part of the year when the temporary population is absent. Assuming the permanent population at 40,000 and allowing a consumption of about 80 gallons of water per head per day, we have total daily use of 3,200,000 gallons. This quantity may be increased somewhat during large conflagrations, so that a storage capacity of about 3,500.000 gallons should be provided, which represent a volume of about 470,000 cubic feet, contained in three rectangular basins of concrete masonry each 130 feet long. 100 feet wide and 12 feet deep, or in four circular steel tanks 104 feet diameter and 14 feet deep. The estimated cost of such storage capacity is about $50,000, including wooden roof, by either plan of construction; and the space required therefor is a lot 365 feet long by 175 feet wide, which is the size of the lot now owned by the city opposite the pumping station at the corner of Kentucky and Mediterranean Avenues.

QUANTITY OF WATER.

As already stated in the foregoing, the proposed 30-inch conduit from Absecon is adapted to the economical delivery of 10,000,000 gallons per day, and the question now arises whether this quantity of water can be permanently obtained at the locality. The minimum delivery of the present wells and

canal at Absecon may be estimated at about 5,000,000 gallons per day, although this limit has not yet been reached; and from the deep wells at the City Pumping Station a probable ultimate minimum of 1,000,000 gallons per day may be anticipated, as it is not likely that a further extensive development of this subterranean source will be attempted. The total probable minimum dry weather yield of the two sources together is therefore about 6,000,000 gallons per day. Hence, to satisfy a prospective maximum demand of 10,000 000 gallons per day, an additional daily supply of at least 4,000,000 gallons must eventually be secured from the mainland at Absecon. On the other hand, if the subterranean supply at the City Station is treated as a reserve, as previously suggested, then an additional supply of 5,000,000 gallons per day must be obtained from the mainland.

To secure this further quantity, it will be necessary either to provide adequate storage on Absecon Creek, and thus deliver into the city mainly surface water, or to undertake an extensive development of the underground supply which appears to be available. In view of the growing general prejudice against surface water supplies, and the large cost of storage, the former course should not be adopted until it has been demonstrated by proper exploration of the subsoil that a satisfactory ground water supply cannot be secured. From the experience gained with the existing wells, however, there is good reason to believe that a large additional quantity of ground-water can be obtained at moderate depth and cost in the vicinity of the Absecon Pumping Station; hence it is recommended that steps be taken to determine experimentally, whether such is the fact. The methods of making this examination have been fully discussed with Mr. Hawley, and need not be recited here. If an adequate volume of ground-water is found the entire problem will be solved in the most economical

manner, and the independent operation of the City Station plant can be permanently discontinued, or considered as a reserve.

In relation to the new pumping engine that may be required with the increased supply, little further need now be said, except that if centrifugal pumps are selected for the low pressure station, they should be of the best possible design, as otherwise a good reciprocating pump will give a higher duty. So far as can now be determined, the efficiency of the former class of pumping machinery is on the whole a little higher than that of the latter at the average low lift which will here prevail; but if the engines are operated at higher speed for a shorter time each day after the aforesaid reservoir capacity is provided in the city, it will probably be found on further investigation that the reciprocating pumps are best suited to the work.

As to the cost of securing a large additional underground supply at the Absecon Station, nothing very definite can now be given, as everything depends on the location and magnitude of the water bearing stratum. From such data as are available, it is probable that tubular wells of at least six inch diameter must be driven to a depth of about 90 feet below the surface of the ground, in order to penetrate sufficiently far into the saturated subsoil, and that the permanent minimum yield of such a well will be about 150,000 gallons per day. On this basis, not less than 33 such wells will be required to secure the desired 5,000,000 gallons per day; and as it will doubtless happen that some of the number will occasionally become choked and require cleaning, it will be prudent to estimate that fully 40 wells must be provided. Furthermore, the distance between the wells may be taken at about 200 feet, so that the aggregate length of piping required in the whole system will be about 12,000 feet, of which perhaps

2,000 feet will be 36 inches in diameter, and 7,000 feet will be 6 inches in diameter, while the remainder will be of various intermediate sizes. With all the necessary appurtenances, such a system of underground water supply will cost, under favorable circumstances, from $40,000 to $50,000, exclusive of the pumping plant, and hence, before it is undertaken, a thorough study of the subsoil should be made.

Concerning the development of surface water storage along the course of Absecon Creek, the data now at hand are too meagre to warrant the formulation of any valid conclusions. The drainage area of the stream above the head of the existing water works canal is about 14 square miles, and with an average rainfall of about 45 inches thereon, it is reasonable to assume that the required volume of storage water is available. The best places and costs of impounding, however, must yet be determined, and this can be done only after proper surveys have been made.

Respectfully submitted,

E. KUICHLING,

Consulting Engineer.

REPORT

TO THE

HON. SAMUEL H. ASHBRIDGE

Mayor of the City of Philadelphia

ON THE

EXTENSION AND IMPROVEMENT

OF THE

WATER SUPPLY

OF THE

CITY OF PHILADELPHIA

BY

RUDOLPH HERING,
JOSEPH M. WILSON
SAMUEL M. GRAY
COMMISSIONERS

PHILADELPHIA
1899

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LIST OF PLATES.

OFFICE OF THE COMMISSION

ON THE

EXTENSION AND IMPROVEMENT

OF THE

WATER SUPPLY

OF THE

CITY OF PHILADELPHIA

Philadelphia, September 15th, 1899.

HON. SAMUEL H. ASHBRIDGE,
Mayor of the City of Philadelphia.

SIR:—In accordance with a resolution of the Select and Common Councils of the City of Philadelphia, adopted April 20th, 1899, authorizing your Honor to select and employ three experts as a Commission to consider and report upon the question of the improvement and extension of the Water Supply for the City, acting in conjunction with the Director of the Department of Public Works and the Chiefs of the Bureaus of Water and Surveys, your Honor was pleased to name for this purpose, the undersigned, Messrs. Rudolph Hering, Joseph M. Wilson, and Samuel M. Gray, all of whom, after being duly advised, made acceptance of their appointment.

At a conference with the Commission, held on May 9th, the various questions to be considered were very fully discussed, and your Honor outlined what was desired, afterwards incorporating the instructions in a letter as follows:—

[Copy]

OFFICE OF THE MAYOR
PHILADELPHIA

MESSRS. RUDOLPH HERING, JOSEPH M. WILSON
AND SAMUEL M. GRAY,

Commission to Investigate the Extension and Improvement of Philadelphia's Water Supply.

May 18, 1899.

GENTLEMEN:—The Director of the Department of Public Works, Mr. William C. Haddock, has informed me that you desire the remarks which I made at our conference on Tuesday of last week, as to the scope of your work, reduced to writing, with a view to the incorporation of the same, in your report. It gives me pleasure to send you herewith as nearly as I can recall, what I said upon that occasion.

The resolution under which your appointment was made passed the Select and Common Councils on April 20th of this year, and is as follows:

"WHEREAS, The quality of water furnished by the "municipality is such as to require purification by filtra-"tion or otherwise, and

"WHEREAS, There are on record in the Bureau of "Water authoritative and exhaustive plans, surveys and "reports heretofore drafted and made by various com-"missions, engineering experts and departmental officials "dealing with the water supply and upon which no "action has been taken. Therefore be it

"*Resolved, by the Select and Common Councils of the* "*City of Philadelphia*, That the Mayor be, and is hereby "authorized and directed to select and employ three "experts to act in conjunction with the Director of the "Department of Public Works, and the Chiefs of the "Bureaus of Water and Survey, to take up the question "of the immediate improvement and extension of the "water supply, provided that a preliminary report shall "be made by said experts within sixty days of their "appointment, and the final report shall be presented "not less than three months thereafter, so that it may be

"presented to Councils immediately after the summer
"recess in September.

* * * * * * * * * *

In outlining what was desired, I took the foregoing resolution as the basis for instructions. Your work naturally divides itself into three great problems, First,—What is necessary for the immediate betterment of our water system. Secondly,—If the remedy be filtration, what is the best method, and Thirdly,—In what direction is it most desirable to extend our present supply, so that for years to come, the water problem may not give anxiety to our people.

Your first duty will be to take up the question of the immediate relief of present conditions. I would request that you visit all of our pumping stations and reservoirs and make a thorough investigation of everything appertaining thereto. I would ask you to take into consideration and compare the waters of the two rivers, ascertaining, if possible, and approximating the decrease in the flow of the Schuylkill River.

It would also be well to consider the Schuylkill Valley as a region of great industrial activity, where manufacturing enterprises must increase in the years to come, with the danger of pollution of the Schuylkill, the natural drain of the Valley, as a consequence. Is it, therefore, wise to continue the Schuylkill as the principal source of our supply?

* * * * * * * * * *

Secondly:—If your investigations show that filtration is the remedy for the conditions which confront us, I would then ask that you recommend a system, calling attention, however, to the fact that slow sand filtration is generally recognized as the best. I would ask a careful estimate as to the cost of installation of a plant, sufficient to filter the entire supply of the city, with the annual cost for maintenance per million gallons daily, this estimate to include depreciation and renewals of plant. In the cost of the installation, I would ask that the proposed sites of the filtering beds be specified, together with the approximate cost per acre. I would ask you to take into consideration whether the severity of the temperature of

the weather in Philadelphia, during the winter months, would not necessitate the erection of roofs over the filtering beds, and how much additional this would cost.

It is also a question whether filtered water could remain in the subsiding basins any length of time, without deterioration. It is but proper for me to call your attention, officially, at this time, to the constant and increasing growth of our municipality and the extension of its business enterprises, and would ask you to take into consideration, in connection, with filtration, whether that system could be extended to accommodate within a reasonable degree, the people of Philadelphia for the next half century.

The third and final duty which devolves upon you under the resolution is to look forward to the future. Personally, I would like to see a lasting solution of the water question. For forty years this city has been confronted with a problem, both as respects quality and quantity. Measures which brought about temporary relief alone have been instituted, but the question has never ceased to be a vexatious burden to succeeding generations. I would ask you to consider the present consumption of water, its increase and how it probably will increase in the future, and to recommend what means should be introduced to give the City of Philadelphia an ample supply, without unnecessary restrictions, for at least fifty years to come.

Your suggestion, I might add, should be broad enough to provide for a subsequent extension of the system proposed, so that the water problem could be solved for at least a century.

Should you be able to cover this vast problem, so as to make a final and definite report, to be laid before Councils when they assemble in the Fall, you will have performed a magnificent work, not only for this generation but for generations yet unborn. Your task is no light one. It has puzzled the best engineering brains for one hundred years or more, and if you solve the question, it will not only redound to your honor, but increase the health of the community, advance all its varied interests, and be a monument forever to the credit of Philadelphia.

It will strengthen and stimulate our people in all their various lines of activity, and place us far in advance of all other cities on this continent, if not in the world.

Very respectfully yours,

[Signed] SAMUEL H. ASHBRIDGE,

Mayor.

These instructions, presenting to us a problem of vast proportions, both as to time and scope, placed upon us a great responsibility, in view of the few months at our disposal. As your Honor, however, kindly granted us immediately all the assistance we required, it has been possible to cover the ground with such care that we can now report our conclusions on at least the essential features of the problem, with the fullest confidence that they present the means of providing a supply of water for the City of Philadelphia equal to the best, and capable of being secured at a reasonable cost.

At meetings had from time to time with your Honor, as occasion required, various modifications in the details of procedure were brought up and discussed, in further amplification of the subject. All of these modifications have been duly considered and acted upon.

The resolution authorizing our appointment required that, in considering the subject placed before us, we were to act in conjunction with the Director of the Department of Public Works, Mr. William C. Haddock; the Chief of the Bureau of Water, Mr. John C. Trautwine, Jr., and the Chief of the Bureau of Surveys, Mr. George S. Webster. These gentlemen have aided us by furnishing desired information during the entire investigation, and we take pleasure in acknowledging our indebtedness on this account. Special mention in this respect should be made concerning the assistance rendered by the Chief of the Bureau of Water, who supplied us in ready and convenient form not only with the material already available in

his office, but also with information prepared at our request and collected by him elsewhere.

We desire also to acknowledge our indebtedness to the many engineers, in this country and abroad, who have furnished us with valuable data.

The shortness of time allotted to us made it advisable, in some instances, to draw upon the special experience of certain engineers in other cities. For instance, to verify our estimates of cost for the aqueducts from the Blue Mountains and for the filter plants to be located in this city, we obtained the co-operation of Mr. Charles S. Gowen, Principal Assistant Engineer of the Croton Aqueduct Commission, New York, and of Mr. William B. Fuller, late Principal Assistant Engineer of the Albany Filter Plant.

Finally, we desire to mention, with credit, the services of Mr. James H. Fuertes, Civil Engineer, who with much skill, untiring devotion and unusual dispatch, collected for us most of the information we required.

A preliminary report of progress was submitted on July 3rd, in accordance with your instructions, and we have now the honor to present our final report.

INTRODUCTORY.

It is proper that we preface our report with a brief review of the present works, since you have asked our suggestions as to the measures which should immediately be taken respecting the improvement of the existing plant.

Population.

The City of Philadelphia contains at the present time about 1,300,000 inhabitants. It is difficult to make a reliable estimate of the future increase in population, as much depends upon local conditions. After a careful study of the rate of increase in the past, and a compari-

son with the growth of other cities, a conclusion has been reached. Plate XVI illustrates how this was obtained. One diagram shows the actual growth of the city to 1890, another shows the percentage of increase of population by decades, including the probable percentage of future increase, and a third diagram shows the probable population as far into the future as the year 1950. This last diagram gives, for the year 1925, a maximum of 2,250,000 and a minimum of 1,900,000 persons, and for the year 1950 a maximum of 3,300,000 and a minimum of 2,700,000 persons.

We have thought it proper to provide at present for a population of 1,300,000 persons and also to make estimates of cost for works serving 3,000,000 persons.

Existing Conditions.

The present supply is taken from the Delaware and Schuylkill rivers within the geographical limits of the city, about 95 per cent. of it from the Schuylkill, and the remaining 5 per cent. from the Delaware. All of the water is pumped, normally to reservoirs, artificially constructed on elevated sites, from which it is distributed through cast iron pipes. Certain elevated suburban districts are supplied by high-service pumping stations, drawing from the reservoirs.

Delaware River.

The Delaware river rises in the southeastern part of the state of New York, about 190 miles above Philadelphia, and for about 130 miles of its course, before reaching Philadelphia, it forms the boundary between the states of Pennsylvania and New Jersey. The upper part of its watershed is mountainous and very sparsely settled. At the Delaware Water Gap it breaks through the Blue Mountain, and from that point downward its course

becomes generally less precipitous, until, below Trenton, it is a tidal estuary, flowing through alluvial flats, generally under a high state of cultivation, but with no very large towns.

The area of the water-shed is about 8,600 square miles. The principal affluent of the Delaware, above Philadelphia, is the Lehigh, which flows through the anthracite coal fields of the same name, and reaches the Delaware at Easton, 75 miles above Philadelphia. The area of the Lehigh water-shed is 1332 square miles.

The largest towns upon the banks of the Delaware, above Philadelphia, are Easton, Pa., 14,500 population, 75 miles above Philadelphia; and Trenton, the capital of New Jersey, 57,500 population, 30 miles above Philadelphia.

But little manufacturing is carried on along the banks of the Delaware above Philadelphia; but the Lehigh valley is a very important iron manufacturing district.

The principal source of pollution of the Delaware, as a source of water supply for Philadelphia, is the city itself. The river, within the city limits, being tidal, the water taken is subject to pollution from the city's sewers, several of which discharge large quantities of sewage at points within a mile of the present intake, both up and down stream.

The Delaware receives from the Lehigh, at Easton, the drainage of the Lehigh anthracite region, and, at the same time, passes through a broad limestone belt, traversed also by the Schuylkill. Below Trenton it receives the washings of the alluvial plain through which it flows. Its volume, however, is so large that the effects of these influences are seldom very strongly marked. The water of the Delaware, at Philadelphia, is quite soft, forming no scale in boilers.

During the drought of 1895, the water of the Delaware,

opposite Market street, Philadelphia, was sensibly brackish at high tide, but no such effect was noticed at the pumping station at Lardner's Point.

The Delaware river water above the Water Gap is of fair quality. The water from its mountain tributaries, between the Gap and Bushkill, is equal to the best of mountain waters, but the river itself brings down the pollutions from Port Jervis and other towns situated on its banks above. Below the Gap the river is augmented by tributaries, and particularly by the Lehigh river, which brings considerable pollution from Easton, Bethlehem, Allentown and other cities. Further down, the river, by its increase of size, becomes relatively less polluted, but it receives the sewage from a number of towns as far down as Philadelphia. Owing to the large volume of flow, the dilution of the impurities is much greater than is the case with the Schuylkill water.

The Delaware water contains only about one-third the amount of sulphate of lime found in the Schuylkill water, which accounts for the superior softness of the former, and, therefore, its advantage for use in boilers.

The Lehigh river, below White Haven, is not only much contaminated with sewage, but also, for a considerable portion of its length, with coal refuse. The territory east of the river between the Lehigh Gap and White Haven, and the entire water-shed of the river above White Haven, furnish water free from natural and artificial impurities, and, like the tributaries of the Delaware above mentioned, would provide an excellent mountain water supply.

The Tohickon creek flows into the Delaware at Point Pleasant, and Big and Little Neshaminy creeks enter the Delaware river below Bristol. The waters of these streams would require storage and filtering. Lack of time prevented a reconsideration of these projects on the basis of filtering their supply. They were fully described in the

annual reports of the Bureau of Water from 1883 to 1886. The Tohickon creek furnishes a better water than either of the Neshaminy creeks, but, in our opinion, with the light that is now available regarding the sanitary dangers of raw water obtained from populated districts, and with the known efficacy of filtration, we do not now consider these streams available sources without a prior filtration. It may be that they can be made available in the future, by filtering their water and delivering it into the reservoirs of the City by gravity at an elevation of 170 feet above city datum. The same may be said of the lower Perkiomen sources.

Schuylkill River.

The Schuylkill river, which joins the Delaware at the southern extremity of Philadelphia, rises in the anthracite coal region of Schuylkill county, Pennsylvania, about one hundred miles above Philadelphia. In its generally south-easterly course, it intersects most of the ridges and geological formations traversed by the Delaware below the Water Gap.

The principal towns on the Schuylkill are:

	Distance above Philadelphia. Miles.	Population, 1890.
Pottsville	80	14,120
Reading	60	58,660
Pottstown	38	13,280
Phœnixville	26	8,500
Norristown	22	19,790

The water-shed area of the Schuylkill is about 1,915 square miles.

At Port Clinton, the Schuylkill breaks through the Blue Mountains, forming a gap similar to the Delaware Water Gap. Below that point it intersects generally the

same ridges and the same geological formations traversed by the Delaware.

The Schuylkill is tidal as far up as Philadelphia, where the flow of the tide is stopped by the Fairmount Dam.

The range of tide in the Schuylkill at Fairmount, below the dam, is about 6 feet.

Fairmount dam furnishes water power for the seven turbines at Fairmount station. These are the only water power works employed by the city.

Many years ago the navigation of the Schuylkill was improved by the construction of a series of dams and canals, forming a slack water navigation extending from Philadelphia to Pottsville, a distance of about 100 miles. Its navigation is still in use from Philadelphia to Port Clinton, a distance of about 77 miles. It is under the control of the Philadelphia and Reading Railway Company, lessee of the Schuylkill Navigation Company.

The available storage capacity of all the existing pools above Philadelphia, is 563,000,000 cubic feet, or about 4,200,000,000 gallons.

With the exception of the lowest, or Fairmount Dam, which was built by the City of Philadelphia, all the works were built by the Schuylkill Navigation Company, in the early part of the present century.

The Schuylkill flows through a densely populated region, and its banks are dotted by important manufacturing towns.

The anthracite coal mines pour into the river large quantities of sulphuric acid, which, however, is completely neutralized by the subsequent passage of the river through the limestone beds which it intersects, so that the water, upon reaching Philadelphia, has a hard or alkaline reaction, and it gives considerable trouble by the formation of scale when used in the boilers.

In 1885 the city, for the better protection of the water

of the Fairmount pool, constructed an intercepting sewer along the east bank of the river, and this sewer now receives the discharge from the numerous and extensive mills from Manayunk within the city limits, and pollution from many other sources, and discharges it into the river below the Fairmount Dam, or below the pools from which the city pumps its water.

The ordinary low-summer flow of the Schuylkill river at Philadelphia is about 200,000,000 gallons per day, and the extreme minimum flow should, perhaps, for safety, be taken as low as 150,000,000 gallons per day.

When the Schuylkill river was originally selected, the population of the city was small. Its buildings were grouped along the Delaware river, extending hardly half way across to the Schuylkill river, which then furnished an excellent supply. Few towns existed along its banks, and the water was almost uncontaminated by sewage, by the output of coal mines or by other impurities. Time has changed all this.

For some years the development of the coal regions caused no perceptible injury to the water, although a considerable quantity of acid from the mines mingled with it; thanks to the limestone beds, already mentioned.

Of late years, however, water is being very extensively employed in the coal breakers as an aid in the separation and cleaning of the coal, and the mountains of culm, which have been accumulating for years about the mines, are now being worked over by a similar process, with the result that a large amount of coal dust is washed down the river to the city, especially in freshets.

The progressive settlement and cultivation of the country have brought another increasing trouble. The ploughing up of the soil allows the rains to wash quantities of mud into the streams, until the water, originally clear and palatable, is now often most objectionable, being repulsive in appearance and unpleasant to the taste.

A vital trouble, however, has arisen from the great increase in population and from the almost unrestricted disposal of much of the sewage and the refuse of manufactories, these matters entering directly into the streams, until the water, in its present condition, has become dangerous to health and unfitted for domestic use.

In 1884–5 a sanitary survey of the Schuylkill valley was made by the Water Department, and the reported facts and figures indicate that this pollution was serious even then, or fifteen years ago. Fairmount Park was originated and laid out for the purpose of controlling the banks of the river and protecting the water from pollution. Since then, further efforts have been made for the improvement of the conditions within the park, mainly by the construction of the intercepting sewer along the east bank of the river. But there is at present no adequate protection against pollution of the river beyond the City line, and matters remain very much as they were years ago. An investigation of the river reveals contaminations of the most abominable kind. On one of our recent visits we saw at least a dozen privies discharging their contents directly into the Schuylkill river between Conshohocken and Norristown.*

A systematic examination of the Schuylkill water, undertaken two years ago by the Bureau, has since been regularly continued. Samples have been taken twice a week at the intake of the Spring Garden Pumping Station, and a determination has been made of the organic and mineral constituents. The results furnished give information of practical value on the subject of purifying the water for the city's use.

A comparison between the samples taken from the intake, from the reservoir, and from the outlets of service

* See also: A joint report of the Philadelphia and Pennsylvania Boards of Health on the sources of pollution of the Schuylkill river from Philadelphia to Reading, 1898. Illustrated.

pipes, shows a gradual diminution in the amount of organic matter in the water; in other words, an improvement after leaving the river. Observations in regard to this matter have almost uniformly given the same results, due, no doubt, to sedimentation, to oxidation, or to both.

When the river is frozen over, the water is generally clearer and brighter than at other times, and the amount of organic matter is less. This would lead to the inference that a large amount of impurity is usually received from the washings of the surface of the country from rain water.

The amount of suspended matter in the Schuylkill and Delaware waters has been determined by Mr. James H. Eastwick, of the Bureau of Health. The results are given in Appendix I to this report.

The greatest amount of suspended matter is that reported on March 13, 1899, when it reached 1,026 parts per million parts of water. While this amount appears excessive, and represents very muddy water, yet it does not equal that found in the Ohio river water, which is stated by Mr. G. W. Fuller, in his Cincinnati report, to have been as great as 2,333 parts per million, or over twice the amount which is considered very objectionable in the Schuylkill river.

This large amount of suspended matter indicates that at times a filtration of the Schuylkill water must necessarily be preceded by sedimentation, to remove most of the suspended matter, and that at periods of great turbidity even a coagulant would be of great service and economy, for the purpose of more rapid and thorough precipitation.

The tables show that the Schuylkill river clears up rather rapidly. For instance, the suspended matter was reduced from 1,026 parts to 130 parts per million in seven days.

At low stages of the Schuylkill river, 80 parts of alkaline sulphates per million have been found in the water, indicating the degree of its permanent hardness. During freshets the quantity diminishes to about one-third of this amount. Samples of very turbid Schuylkill water, treated with sulphate of alumina, have shown a greatly accelerated sedimentation. The mineral constituents of a sample of the Schuylkill water, taken at the intake of the Spring Garden station, October 29, 1898, were:

Sulphate of Lime and Magnesia........	80	parts per million.
Carbonate of Lime and Magnesia......	60	" "
Chloride of Sodium........................	10	" "
	150	" "

Those of a sample taken on March 13, 1899, were:—

Sulphate of Lime and Magnesia........	24	parts per million.
Carbonate of Lime and Magnesia......	38	" "
Chloride of Sodium........................	4.64	" "
	66.64	" "

These analyses give approximately the extremes in mineral constituents, the first having been taken during a long drought and the second after heavy rains.

The principal tributaries of the Schuylkill river, above Reading, on account of their contamination from the coal regions, are not available as a water supply. One of its lower and larger tributaries, the Perkiomen creek, in the upper 120 square miles of its water-shed, furnishes a good mountain water. Its water is rendered but slightly turbid by rains, and it is comparatively free from sewage pollution. The water from lower branches of the Perkiomen creek, such as the West Swamp creek and the North East Branch is highly discolored after rains, and also much more polluted, on account of the larger population residing on their watersheds.

Present Works.

The plant of the Philadelphia Water Works, one of the largest in the world, comprises:

(1) Thirty-seven pumping engines, with a rated total pumping capacity of 399,040,000 gallons daily. Of these pumps, thirty are operated by steam, and seven (turbines) by water power.

(2) Eleven reservoirs, two stand-pipes and three tanks, with a combined capacity of 1,417,860,000 gallons.

(3) A system of more than 1,250 miles of water mains, varying in diameter from 4 to 48 inches, together with the necessary valves, fire hydrants, etc.

(4) Fairmount and Flat Rock dams, the latter belonging to the Schuylkill Navigation Company.

The pumps vary in capacity from 250,000 to 30,000,000 gallons each per 24 hours, and are contained in ten pumping stations, five of which obtain water directly from the Schuylkill river and one from the Delaware river; four are high-service pumping stations.

The five stations located on the Schuylkill river are the Fairmount, where pumping is done by water, Spring Garden, Belmont, Queen Lane and Roxborough, where pumping is done by steam. The station on the Delaware river is at Frankford, where pumping is done by steam. The four high-service stations are at Belmont, Mount Airy, Chestnut Hill and Roxborough.

Of the five Schuylkill stations, four, viz.: Fairmount, Spring Garden, Belmont and Queen Lane, take their water from the lowest or Fairmount pool, formed by the Fairmount dam, while the remaining, or Roxborough station, takes its water from the Flat Rock pool, formed by the Flat Rock dam, belonging to the Schuylkill Navigation Company.

Pumping Stations.

Fairmount Pumping Station.—The station contains seven turbine wheels, with pumps having a combined capacity of 33,290,000 gallons in 24 hours, lifting the water into Fairmount reservoir.

The new or lower house contains:

No. 1 turbine with 2,000,000 gallons daily capacity.
No. 3 turbine with 5,330,000 gallons daily capacity.
No. 4 turbine with 5,330,000 gallons daily capacity.
No. 5 turbine with 5,330,000 gallons daily capacity.

The old or upper house contains:

No. 7 turbine with 5,100,000 gallons daily capacity.
No. 8 turbine with 5,100,000 gallons daily capacity.
No. 9 turbine with 5,100,000 gallons daily capacity.

All the pumps excepting Nos. 1 and 3 are so connected that they can pump also to Corinthian Reservoir, having a slightly higher elevation. Nos. 1 and 3 can pump only into Fairmount Reservoir.

Spring Garden Pumping Station.—This station contains forty-four boilers and nine steam pumping engines, giving a total daily capacity of 170,000,000 gallons. When the water in the river is clear, No. 8 Worthington engine pumps directly into the Queen Lane distribution system.

The old or upper house contains the following pumping engines:

No. 5 Southwark,	with 20,000,000 gallons daily capacity.
No. 6 Simpson,	with 10,000,000 gallons daily capacity.
No. 7 Cramp,	with 20,000,000 gallons daily capacity.
No. 8 Worthington,	with 10,000,000 gallons daily capacity.
No. 11 Gaskill,	with 20,000,000 gallons daily capacity.

The new or lower house contains:

No. 9 Worthington,	with 15,000,000 gallons daily capacity.
No. 10 Worthington,	with 15,000,000 gallons daily capacity.
No. 2 Holly,	with 30,000,000 gallons daily capacity.
No. 3 Holly,	with 30,000,000 gallons daily capacity.

Belmont Pumping Station.—At this station there are nineteen boilers and four Worthington duplex pumping engines, aggregating 38,000,000 gallons daily pumping capacity.

The water pumped is delivered into Belmont reservoir.

The house contains the following pumping engines:

No. 1 Worthington with 5,000,000 gallons daily capacity.
No. 2 Worthington with 5,000,000 gallons daily capacity.
No. 3 Worthington with 8,000,000 gallons daily capacity.

A rough wooden shed contains:

No. 4 Worthington with 20,000,000 gallons daily capacity.

Queen Lane Pumping Station.—Here there are twenty-four boilers and four Southwark vertical triple expansion engines, with single acting pumps, having a total daily capacity of 80,000,000 gallons.

Roxborough Pumping Station.—At this station there are nineteen boilers and three pumping engines, with a total capacity of 24,500,000 gallons daily:

No. 1 Southwark with 12,000 gallons daily capacity.
No. 2 Worthington with 5,000,000 gallons daily capacity.
No. 3 Worthington with 7,500,000 gallons daily capacity.

The Worthington pumps Nos. 2 and 3 are duplex and lift directly into the old reservoir, and, when this is full, into the new reservoir.

The No. 1 Southwark is a cross-compound bell-crank engine with vertical steam and horizontal water end, and usually forces its water directly to Germantown and Mount Airy reservoirs. Some of the water flows into Mount Airy reservoir and is pumped into the high-service mains.

It is probable that the pumps do not pump over 75 per cent. of their rated capacity.

The city has contracted for four new Worthington

pumping engines, each to be of 5,000,000 gallons daily capacity.

Frankford Pumping Station.—This pumping station has twelve boilers and three pumping engines with an aggregate capacity of 42,000,000 gallons daily. The pumps are:

No 1 Cramp with 10,000,000 gallons daily capacity.
No. 2 Wetherill with 10,000,000 gallons daily capacity.
No. 3 Southwark with 22,000,000 gallons daily capacity.

The Southwark is a vertical cross-compound engine. It was tested by a Venturi meter and by a weir measurement, showing less than 5 per cent. loss by slip.

The Cramp engine is vertical cross-compound and is in good order. It has not been tested, but it is stated that the slip is not more than 2 per cent.

The Wetherill is a horizontal Corliss cross-compound engine. When tested by a Venturi meter and by a weir, it indicated less than 2½ per cent. loss by slip. This engine is more sensitive to a variation of pressure in steam or water than the other two engines. With a loss of pressure in steam of five pounds or an increase in pressure of water of but a few feet, the engine will slow down.

Belmont High-service Pumping Station.—This station has two pumps, No. 1 Worthington, with 2,000,000 gallons daily capacity, and No. 2 Snow, with 500,000 gallons daily capacity, and it has four boilers.

The Worthington engine was bought in 1869. A contract has recently been made for a new 5,000,000 gallou Worthington engine.

These pumps can take water either from Belmont reservoir or from the mains leading to it. They pump directly into a standpipe near by.

Roxborough High-service Pumping Station.—It is located near the old reservoir, and contains a Worthington pump-

ing engine of 5,000,000 gallons daily capacity and four boilers. It takes water either from the old or from the new reservoir, as the case may be, and pumps it into a standpipe near by, from which it flows to the water tower at Chestnut Hill.

The pump at this station was first put in service in 1871 at Otis street wharf for the Kensington Water Works, to pump Delaware water into the Lehigh reservoir. The city has contracted for a new 5,000,000-gallon pumping engine.

Mount Airy High-service Station.—This station adjoins the Mount Airy reservoir, and contains four boilers and three pumping engines, having an aggregate capacity of 3,000,000 gallons daily, as follows:

No. 1 Davidson, with 1,000,000 gallons daily capacity.
No. 2 Davidson, with 1,000,000 gallons daily capacity.
No. 3 Knowles, with 1,000,000 gallons daily capacity.

These pumps take their water from Mount Airy reservoir and deliver into the water tower at Chestnut Hill.

Chestnut Hill High Service Station.—This station contains one Knowles pumping engine, with a capacity of 1,000,000 gallons; one Worthington pump, with a capacity of 500,000 gallons, and one boiler.

A list of the City reservoirs and standpipes, with their capacities, depths and elevations, is given in Appendix II.

Pumping Systems.

The Frankford station, on the Delaware river, forces its water through two parallel mains, 4½ miles long, to the Wentz Farm reservoir, at an elevation of 167 feet, which supplies Frankford and other districts in the north-eastern portion of the city.

The Lehigh reservoir, at Sixth street and Lehigh avenue, is filled by gravity from the Wentz Farm reservoir, but owing to its low elevation, it is only occasionally used for distribution.

Fairmount station, with its seven turbines, pumps into the Fairmount reservoir, close by, with an elevation of 94 feet, and into Corinthian reservoir, distant about one-half mile, with an elevation of 120 feet. These reservoirs supply a small district comprising the lowest levels in the city, and the elevation of Fairmount reservoir is so slight that, although usually kept full of water, it is now used only occasionally for distribution.

Spring Garden Pumping Station, about half a mile above Fairmount, pumps about one-half of all the water consumed by the city, sending it into the largest, or East Park, reservoir, about one-half mile distant, with a capacity of 689,000,000 gallons. This reservoir supplies the greater part of the city proper. A portion of the supply from Spring Garden goes also to the small Spring Garden reservoir, for the exclusive supply of Girard College, which is in the vicinity of the reservoir.

The Belmont works pump the entire supply of West Philadelphia, sending it into the Belmont reservoir, distant about one mile, with an elevation of 212 feet. From this supply a special 12-inch main crosses the river for the exclusive supply of the City Hall, at Broad and Market streets.

The Queen Lane Pumping Station, with the reservoir of the same name, distant one mile, was constructed for the relief of what was formerly known as the "direct pumpage district," which was supplied from the Spring Garden station. The Queen Lane system, although not yet completed as originally designed, is now in full service, and direct pumpage is now used only occasionally, and never when the river is in relatively bad condition.

The Roxborough station, drawing from the upper, or Flat Rock pool, pumps into the old and new Roxborough reservoirs, for the supply of Roxborough, Manayunk, Chestnut Hill and Germantown.

The nominal pumping capacity of all the works pumping from the rivers is nearly 381,000,000 gallons, but the fact that the pressures throughout the city are low, and that incipient water famine exists at many points, show that the actual pumpage capacity is barely equal to the demand.

Repairs Immediately Needed.

Fairmount.—The roof of the upper house leaks freely, so that it is impossible to protect the pumps and machinery from injury by rust. The internal appearance of the house is so unsightly that it is deemed proper to exclude the public from it. The roof over the lower pump-house will shortly need renewal. The forebay leading from the river to the flumes which conduct the water to the turbines is obstructed by a deposit of sand and mud in that portion where the velocity of the water is reduced. The form of the forebay, as seen in plan, should be changed as proposed by the Bureau of Water.

Spring Garden Pumping Station.—Both bell-cranks of No. 5, Southwark Engine, have been broken and renewed, and both pump chambers are now badly cracked in spite of patches applied for the purpose of preserving them. In No. 7 Cramp engine the pump cylinders are cracked and should be repaired. The large new Holly engines, Nos. 2 and 3, are crippled by the cracking of their pump chambers, five of these having cracked in No. 2, and six in No. 3. Contracts have been awarded for replacing six of these chambers, and provision should immediately be made for replacing the remainder.

The fly-wheel of No. 11 Holly-Gaskill engine fits its shaft imperfectly, and it is therefore difficult to hold it in place. This defect should be remedied, and the diaphragms and valves of the pumps should be renewed where necessary.

Each of the new Holly pumps Nos. 2 and 3 is connected directly with the river by two 48-inch pipes. All the other pumps take their water from a forebay which is supplied by one 10-foot conduit and two 48-inch pipes. This forebay is partially filled with sand, which interferes with the operation of the pumps, and has to be removed at considerable expense, besides forming a bed for the growth of long grass, which, during the summer, requires that four men be kept constantly at work keeping the forebay clear.

New conduits should at once be built through this forebay, and the latter then filled up, as recommended by the Bureau of Water.

Belmont Pumping Station.—The diaphragms and steam valves of Worthington Engines Nos. 1, 2 and 3 are in poor condition and should be repaired.

No. 4 Worthington High-duty Engine, since its removal from Belmont to Spring Garden in 1894–95, has remained unprotected except by a rude frame shed erected by employees of the Bureau. Designs for a new engine house have been prepared. A suitable house for this engine should immediately be constructed.

Queen Lane Pumping Station.—Owing, probably, to the admission of air through the joints of the long suction main, the pump chambers in the four pumps at this station have been cracked. Some of them have been replaced by new pump chambers. The remaining ones should immediately be replaced, and the suction mains should at once be lowered so as to discharge by gravity into a well placed as nearly as possible directly under the pumps.

The coal shed and tunnel for the proper supply of coal to the station, designed by the Bureau of Water in 1895, should at once be constructed in order to save the

present extra cost of about 23 cents per ton for handling the coal.

Roxborough Pumping Station.—No. 1 Southwark engine has long been in a precarious condition, and within the last few weeks it has finally become so fractured as to place one-half of it out of service.

Inasmuch as proper repairs to this engine would be expensive, we recommend that it be abandoned when it reaches a condition forbidding its further use.

This station has long been unable to cope with the demands upon it.

With the recent breakdown of the large Southwark engine, the conditions have become even more critical, and a new 3,500,000-gallon Worthington pumping engine has been purchased.

Contracts have been awarded for four new Worthington pumping engines, each of 5,000,000 gallons daily capacity. When these are installed, the annoying conditions in the district will be materially relieved, and it will then be possible to make needed repairs to the present Worthington pumps.

Frankford Pumping Station.—Owing to the insufficiency of the distribution system by which the water is delivered from the Wentz Farm reservoir, this station has, at present, a surplus of pumpage capacity and the engines are generally in good condition.

High Service.—At Belmont and at Roxborough high-service pumping stations, the operations have long been carried on under precarious conditions, owing to the fact that each has had only one pumping engine of capacity sufficient for the requirements of the district, but contracts have recently been awarded for a new 5,000,000-gallon pumping engine at each station.

Mount Airy Pumping Station.—There are no special requirements at this station.

Chestnut Hill High-service Station.—The two small pumps at this station, when in operation, take water from an adjacent well, fed from a reservoir, which is supplied partly by springs and rain water, and partly by overflow from the pumpage of Mount Airy and Roxborough high-service stations.

Proposed Frankford High-service Pumping Station.—Contracts have recently been awarded for the construction of a high-service pumping station adjoining the Wentz farm, or Frankford reservoir, for the purpose of supplying the village of Fox Chase, distant about two and one-half miles, and the intervening district.

A 3,000,000 gallon pumping engine has been ordered for this station from the Holly Manufacturing Company, of Lockport, N. Y.

Reserve Pumpage Capacity.—If the present system of pumpage and distribution is to be maintained, it is highly advisable to furnish additional machinery at the several pumping stations, except the Frankford station, in order, not only that there may be sufficient capacity for the demand, but also a surplus in case of break-down or needed repairs.

Cost of Operation.

In Appendix IV is given a table, in itemized form, showing the earnings and expenditures of the Bureau of Water for each year of the ten years from 1889 to 1898, inclusive.

In column "e," of this table, are given the expenditures upon pumping stations and reservoirs, including salaries and wages of all employees at pumping stations and reservoirs, fuel, lighting, repairs to boilers and machinery, ordinary repairs to reservoirs, and all other expenses, for operation and maintenance and incidental to buildings, grounds and reservoirs.

It is with the figures given in this column that our estimates of the annual expense in each of our several projects should be compared. The other columns represent also expenditures for general maintenance, operation and extensions. If the entire expenditure, necessary for the City's water supply, is desired, the figures in these columns should be added to our figures, which represent only the cost of delivering water into the reservoirs. In making such comparison, however, it must be borne in mind that in our estimates we have included interest on the cost of construction and an allowance for depreciation, items which are not included in the Bureau's figures in column "e." Deducting these, we find our estimates lower than the expenses reported by the Bureau. This difference may be accounted for by two facts, viz.:

(1). In our estimate we have not included maintenance of stations and grounds, and certain other general items included in the Bureau's figures.

(2). We have estimated upon a somewhat less consumption than the quantity now actually pumped, believing that with reasonable provisions for preventing waste the consumption can presently be reduced below our estimates.

The cost of maintaining the high-service stations and the annual expenses of the distribution system, of the construction and repair shop, and of administration, are common to all projects. Hence we have not included them in our estimates, these being intended, primarily, to afford a means of comparison between different projects.

For the same reason, and although we have included the cost of laying such mains as will be necessary for bringing the water from the new sources, or from the filter stations, into the distributing reservoirs, we have not included the annual cost of extensions of the distribution system.

Water Consumption.

Quantity Furnished in Philadelphia.—The latest annual report of the Bureau of Water, that for 1898, gives 102,241,835,372 gallons as the total amount of water pumped during the year, including the double pumpage for high service stations. It states that the "average daily pumping was 272,670,777 gallons" and, estimating the population of the City at 1,400,000, the consumption was 196.2 gallons per capita per day.

The Bureau freely admits that, in spite of allowances on account of slip and other defects in the pumps, these figures, based on the plunger displacements of the pumps, exaggerate the actual quantities of water pumped. Recent observations, made by the Bureau of Water with the Venturi meter, at certain of the pumping stations, indidate that the actual average daily pumpage in 1898 was not more than 220 million gallons, or 169 gallons per capita per day.

We recommend that Venturi meters be placed on all the pumping mains, in order to measure the actual quantity of water pumped at each station.

The records of the Bureau of Water, based upon plunger displacement, with allowance for slip, etc., show a consumption of water per capita per day of only 36 gallons in 1860, 54 gallons in 1870, and 68 gallons in 1880, during a period when water was lavishly used by householders in daily washings of pavements, etc., now much less general. A gradually increased and more universal introduction of sanitary appliances, closets, lavatories, baths, elevators, etc., accounts for some of the recent increase in the consumption of water. When it is found from the records that the per capita consumption in 1890 had mounted to 132 gallons, and in 1897 to 212 gallons, it is evident that the figures do not represent the actual use

per capita per day, but that there is added an unnecessary waste.

Quantity Used Elsewhere.—On Plate XVI. a diagram shows the quantity of water consumed in various cities between the years 1860 and 1898, per capita per day, as compared with that consumed in Philadelphia. The figures in the vertical line to the left give the per capita consumption for the years indicated on the horizontal line at the foot of the diagram.

The consumption of water per capita, as deduced from the total population and the total consumption, does not always furnish a true statement of the average amount actually used by each individual, particularly when cities are newly supplied with water, as many of the residents may, in the earlier days of the water plant, be supplied from other sources, and in such cases, a computation based upon the total population gives, of course, too low a consumption per capita. As the number of consumers increases, the error diminishes.

Philadelphia is represented on the diagram by a heavy line. Buffalo, N. Y., and Washington, D. C., are the only cities exceeding Philadelphia in the per capita rate, and it is noticed that the Buffalo consumption has been decreasing quite rapidly since 1895, due to some reduction of waste. Some cities show remarkably uniform results, for instance, Montreal, Quebec, and Glasgow, in Scotland. Many of these cities have introduced meters, the effect of which will be discussed further on.

Quantity Required in Philadelphia.—Careful estimates of the amount of water required per person, on the most liberal basis, give results considerably below the probable present consumption. The investigations of the Bureau show that there certainly is a large amount of unnecessary and preventable waste throughout the city.

After giving this subject serious study we have decided

that about 150 gallons per capita per day, or a total of 200,000,000 gallons per day, would be an ample and even liberal allowance for the actual requirements of the present population. Our estimates of cost are, therefore, based on this amount of water being required at present.

In the year 1950, when the population will probably have increased to three million inhabitants, the supply presumably needed will be 450,000,000 gallons per day.

Meters.—No restriction should be placed upon the use of water required for health, comfort and cleanliness; nor should a part of the community be encouraged to deprive another part of its full quota of water. We are therefore emphatically of the opinion, and strongly urge, that all practicable means should be adopted to secure a fair and equitable distribution of the City's water.

We know of no better means to this desirable end than the introduction of water meters, not only for all business properties and manufacturing establishments, but also for such private consumers as are found, by the Department of Public Works, to be carelessly wasting water from the public supply. This remedy is available and simple, and it has been already adopted in many cities with entire satisfaction.

Plate XVII shows graphically the decrease in consumption per tap in a number of cities where meters have been introduced. In 1880, the City of Milwaukee, Wisconsin, had only 26 meters and the daily water consumption per tap was 1,781 gallons. In 1898 it had 22,096 meters. with a daily consumption per tap reduced to 644 gallons, About 70 per cent. of all private buildings, all railway stations, all business properties and manufacturing establishments were metered. There remain only 30 per cent. of consumers whose supplies are not metered, and yet the amount generally taken through this 30 per cent. for domestic purposes, equals in amount the whole quantity

of water delivered by the meters to the remaining 70 per cent. Notwithstanding the extravagant waste through the unmetered connections, the total consumption per capita per day was reduced from 220 to 80 gallons. Many other cities show similar results. Our plate shows several of them.

The City of New York, which certainly requires as much water as Philadelphia, consumed in 1898, for the boroughs of Manhattan and Bronx, 121 gallons per capita per day, for a population of about two million inhabitants. It had in use over 35,000 meters in these two boroughs, covering, it is said, every place where water was used extensively for other than domestic purposes.

The report of the Commissioners for the City of Pittsburgh advises very strongly the introduction of meters in connection with their new supply.

The consumption per tap for Detroit, as given on Plate XVI, commenced to decrease after meters came into use, and in 1898 it was only 730 gallons per day as against nearly 950 gallons in 1888. In 1888 the Sunday waste is said to have been from 50 to 60 gallons per capita and the average waste for the entire year was thought to have been from 30 to 45 gallons per capita per day. A system of inspection was established and this appears to have been very effective. A careful record was kept of the condition of the plant, but the per capita waste was still about 6 gallons daily. It is stated that at present practically all manufacturing, business, municipal, public and semi-public consumers and about 4,000 private families have meters.

We earnestly recommend the introduction of meters for the City of Philadelphia with perfect confidence that the private consumer is given full and ample use and enjoyment of all water for his needs and comforts, at no greater cost, and probably, in many cases, even less cost

than the present rates impose. The meter is not proposed to increase the revenue, but to prevent one citizen from depriving another one of his rightful share of water. A private corporation would introduce meters at an early day if not restricted by law, and would at the same time encourage consumption in every way.

The lack of a sufficient supply of water, in various parts of the city, is due either to a deficiency of distributing pipes, to the lack of pressure from the reservoir, to the want of pumping machinery, to a waste of water, which reduces the head, or to two or more of these causes combined. The remedies are apparent.

Deficiency of Local Supply.

There is hardly a district in the city in which some portion is not suffering more or less from want of water. The trouble is greatest during the summer months when more water is needed than at other times. In some locations, as for instance in portions of the Belmont district, it is difficult for days in succession to obtain water even on the second floor of the residences. The natural supposition of the inhabitants is, that the trouble is caused by a lack of reservoir capacity, but this is not the case. It is due to the several causes mentioned above.

Four-inch pipes have been found to be nearly filled by incrustation, and six-inch pipes, laid in 1834, have been found incrusted to the extent of one-half inch in thickness. The only means of remedying this trouble is to lay larger distributing mains.

In several cities corroded mains are reported to have been successfully cleaned with scrapers. The operation has cost about two-thirds that of laying a new pipe, and it obliges the shutting off of the supply during the time

of cleaning. Cleaning the pipe leaves the interior surface in a condition to more readily corrode than before. In some cases such cleaning may be advisable, but it will more generally be preferred to allow the incrustation to continue as long as possible and then to lay a new pipe. If pipes are laid of sufficiently large size in the beginning and thoroughly protected with a proper coating, they will give little or no trouble in this respect.

The shortness of the time at our disposal forbade any attempt to investigate in detail the condition of the city's elaborate system of distribution; and we are therefore, of course, unable to make specific recommendations as to which portions of it should be immediately relaid, or where additional mains should be placed, excepting in such cases where there appeared to us no doubt whatever.

Condition of Reservoirs.

Of the three large reservoirs, East Park, Queen Lane and new Roxborough, the last two have, during the past four years, been re-lined with asphalt. East Park has been in full service ever since its completion, ten years ago, and Queen Lane ever since its re-lining. Owing to inability of the pumps to keep pace with the demand, the new Roxborough reservoir has never been filled; in fact, it has recently been necessary to shut it off from the distribution, to prevent its being entirely emptied. None of the three reservoirs gives evidence of material leakage.

Opportunity has been lacking for systematic observation of the behavior of the smaller reservoirs. Except Wentz farm, which is not in good condition, they are in fair order and repair, and holding their intended quantities of water. A hasty observation of the behavior of Wentz Farm reservoir indicated a very moderate amount of leakage; but it was impossible to ascertain

positively that some of the pumpage did not enter the reservoir through partly-open stops. As the reservoir has but one basin, it cannot be thoroughly repaired without being put out of service.

The coping of the retaining wall at Queen Lane reservoir should be finished, and a new watch-house should be built. The northwest corner of the new Roxborough reservoir has an undesirably steep slope. This should be remedied by carrying the slope across Port Royal avenue.

The Lehigh (or Fairhill) reservoir is too low to be advantageously used at present. With its height increased, it would make a useful clear-water reservoir.

At Wentz Farm, a clear-water reservoir should be constructed on the lot (belonging to the city) adjoining the present one on the east, and between it and the Second street road. The existing structure should then be converted into a similar reservoir.

The Corinthian reservoir, likewise, may eventually be converted into a clear-water reservoir, when the demand for its capacity occurs.

Uses of Reservoirs.

Reservoirs for municipal water supplies are required for the purposes of storage, sedimentation, and distribution.

Storage.

It is well known that the flow of a river or smaller water course varies with the rainfall, that it is greatest shortly after rain storms, and least at the end of a long season of drought. In order to best utilize the flow of a stream, it is, therefore, necessary to provide storage reservoirs in which the flood water is collected and stored, and from which it can be drawn out to augment the flow of the stream when this is low.

Storage reservoirs are also used for the purpose of retaining a supply of comparatively clear river water to be furnished to the city when the natural flow of the streams is very turbid, as, for instance, during the first wash after a storm.

Sedimentation.

When using surface waters, particularly from streams running through territory that is readily eroded, and, therefore, charged with much suspended solid matter, it is desirable to allow the water to come to comparative rest for a short time in order that the suspended matter may settle, and, thereby clarify the water. Settling reservoirs are used for this purpose in either of two ways: By one the water is merely checked in its velocity, but flows through continuously; and by the other the water comes to an absolute rest, and is discharged intermittently. The time necessary for the water to remain in the settling reservoirs, whether by the continuous or intermittent system, depends largely upon the nature and quantity of its suspended matter. It is found that in most cases the deposition which takes place during twenty-four hours is practically sufficient, inasmuch as by far the greatest deposit usually results within this period.

Distribution.

Owing to the fact that the consumption of water in a city varies from hour to hour, and that it is greater during day-time than during night-time, and greater during some hours of the day than during others, it is necessary to provide a reserve within the city sufficient to balance the irregular draughts that may occur. This irregularity of draught is caused mainly by the domestic use of the water; but a conflagration or the bursting of a water main

would also affect it. The larger the city, the less noticeable, comparatively speaking, is the effect due to the draught for a large fire or to the breaking of a pipe, because the regular domestic consumption is then large in proportion to the other draughts. For this reason, distributing reservoirs in large cities may provide for a smaller proportionate daily reserve than those in small cities. In the former, one-quarter to one-half day's supply is ample.

Distributing reservoirs in different parts of the city are used also for the purpose of maintaining approximately even pressures in the pipe system.

Reservoirs in Philadelphia.—In this city reservoirs have been used for all three of the above purposes. It was desirable to provide a sufficient amount of storage, to enable the reservoirs to supply the citizens while the Schuylkill river was running very muddy, and thus somewhat lessen the turbidity of the water as finally turned into the pipes. Incidentally, the reservoirs were also efficacious for the purpose of allowing sedimentation to proceed during the comparatively quiescent state of the water while stored. Thirdly, they were used for the purpose of balancing the irregular draught during the different hours of the day.

At the present day, the people are no longer satisfied by a mere lessening of the turbidity of a city's water supply through sedimentation. Perfectly clear, and practically pure water is now demanded. Storage reservoirs are, therefore, no longer necessary for ordinary river or lake water, unless they are used for sedimentation to be followed by filtration.

Storage reservoirs, for the purpose of compensating the yearly flow of the streams, would be required for this city

only in the event of the supply being taken from the comparatively small streams in the mountainous districts. If the Delaware and Schuylkill rivers are to be used, at points near the city of Philadelphia, the former at least, owing to its large size, constitutes its own storage reservoir, and, therefore, no special structures are needed here for the specific purpose of equalizing the seasonal flow.

Sedimentation or settling reservoirs have been wanted in this city only because the waters of the Delaware and Schuylkill rivers are now used in their raw state, and, particularly the latter, are very muddy after rain storms. If clear mountain water is used, they are not required. If a filtered supply is obtained from these two rivers, sedimentation reservoirs are required to give the water a preliminary clearing.

Distributing reservoirs within the city are wanted only for the purpose of providing for the variation in the daily draught, and they may, therefore, be comparatively small.

Clear-water reservoirs, a term used when filtered water is supplied, are identical with distributing reservoirs so far as their purpose and their sizes are concerned. Inasmuch as filtered water, like spring water, is apt to permit of a rank growth of algæ and similar plants on exposure to sunlight and air, these reservoirs are generally covered to avoid a deterioration of the water. Such a covering is usually of masonry, rather than of wood or iron. The former has the advantage of keeping the water cooler, and also for this reason is less likely to induce the growth of minute vegetal organisms.

In the case of a filtered supply, the Schuylkill and Delaware rivers form the storage reservoirs, like those afforded by the lakes at Chicago and Detroit. There are no artificially built reservoirs within those cities. The only use for clear-water reservoirs in Philadelphia is

for the purpose of providing for the irregular daily consumption, for accidents to the mains, fires, etc. It is, however, necessary, when the sizes of the reservoirs are limited to half a day's supply, to have a sufficient reserve of pumping capacity in case of accidents to any of the machinery.

A surplus of mains and machinery for pumping and for distribution affords as effective protection as does a large surplus capacity of clear-water reservoirs, and is generally less costly and more serviceable.

Quality of Water.

Standard of Purity.—A water for the City's supply should have a bacterial purity fully up to the best recognized standard. It should be clear, palatable, and free from chemical and organic pollutions. These qualities can be obtained by using either natural waters which are free from organic and mineral pollutions, or by artificially purifying waters already polluted.

With regard to natural waters, one of the first steps towards maintaining their purity is to reduce their pollution by every possible means, and principally by enacting and enforcing stringent laws against pollution.

Legislation.—In the State of Pennsylvania the statutes governing the question of preserving the purity of streams are somewhat deficient. Attention may be called to the good results achieved by the statutes enacted in Massachusetts.*

The State Board of Health should have supervision of all sources of domestic water and ice supply, with authority to inspect, to make examinations and analyses, and to enact and enforce regulations for the purpose of preventing pollution and securing proper sanitary protection of all sources of water supply for cities. It should have

* Manual for the use of Boards of Health of Massachusetts, and containing statutes relating to the public health, Boston, 1889.

authority to appoint agents to enforce the provisions of statutes and those of its own regulations.

The Board should have authority, and it should be its duty, to cause investigations to be made and to prohibit the pollution of any water course by any city, town, village or habitation, and to require such modifications in any operation, or plant, as it may deem necessary, for the abatement of the nuisance.

While legislation can do much towards lessening the pollution and thus improving the quality of natural water courses, it cannot wholly eradicate the dangers due to contamination. There will still remain surface drainage from cultivated lands, treated by the ordinary processes of agriculture, the use of legitimate fertilizers, manures, etc., and undetected defilements of a minor character, which cannot be controlled. It is well-known that, with certain diseases, such as cholera and typhoid fever, a very slight pollution by excreta from the patient, may produce widespread and most serious results in any community using the water directly as it comes from the streams. The epidemic at Plymouth, Pennsylvania, after the Centennial Exposition, is one of many cases which have demonstrated this fact.

During the late war strong evidence has come from the Surgeon General's office in support of an already well-known fact that winged insects may carry disease germs from one place to another and thus may infect surface water supplies.

FUTURE SUPPLY.

Earlier Studies.—The subject of obtaining a pure and ample supply of water for the City of Philadelphia is one that has been before the public for nearly half a century.

As early as 1856 suggestions were made for securing better water, and, in 1858, Mr. H. M. P. Birkinbine, Chief Engineer of the Water Department, drew attention to the

Wissahickon Creek, the Delaware and Lehigh rivers at Easton, and the Schuylkill river above Reading.

In 1864 a reconnaissance was made of all the streams around the city, within a radius of forty miles, and a gravity supply recommended from the Perkiomen creek.

In 1867 a special Committee of the Park Commission made a report, concluding that the Schuylkill river could be relied upon for many years if proper means were taken to guard it from pollution.

In 1875 a Commission of Engineers was appointed to consider the entire subject of present and future water supply, with special reference to immediate needs. Owing to the lack of information at their disposal, this Commission made no recommendation as to the question of future supply.

Agitation of the subject was continued by the Water Department and by private citizens, until, in 1882, the imminent prospect of a water famine resulted in the appointment of another Board of Experts. They reported not only that a marked deficiency existed in the capacity of the plant for the required supply, but also that complete and accurate surveys should be made of all available sources from which a future supply might be obtained, and that a thorough investigation should be made of the increasing pollution of the water of the Schuylkill river, with the possibility of its control by engineering works and legislative enactments, so as to restore it in some measure to its "pristine condition of comparative purity and wholesomeness."

The result was the appointment of a corps of engineers under Col. (now General) William Ludlow, Chief Engineer of the Water Department, by whom topographic, sanitary and hydrographic surveys were made, important data collected, and maps and approximate estimates of cost prepared for a supply from all available sources. All

of the information thus secured is contained in the annual Reports of the Water Department of this city.

We have availed ourselves of the data collected by the previous Commissions, and of the surveys, reports, etc., on record in the Water Bureau, particularly of the data contained in the reports made to Col. Wm. Ludlow by Mr. Rudolph Hering in 1883–6, and we have made examination of the various areas of country comprised within the watershed lines of the tributaries of the Schuylkill and Delaware rivers in Pennsylvania, including the Lehigh river. We have considered all available sources of supply and have investigated the question of the pollution and purification of streams. We have also examined the present plant of the Water Bureau, including the reservoirs, the pumping stations and the distribution service.

The possession of still other data would have been desirable, regarding conditions such as the turbidity and pollution of the water of both rivers at different seasons, the tidal distribution of sewage in the Delaware river, particularly at spring tides and when the upland flow is a minimum. The allotted time was too short, however, to obtain such information. Nor would it have brought out any new facts to change our main conclusions, because it affects only details, which can be considered later.

Character of Present Supply.

The water supplied to some parts of the city is scarce in quantity, and in all parts inferior in quality.

As already stated, the pressures throughout the city are generally lower than they should be, and many important districts are almost entirely without a supply, notwithstanding that several of the pumping stations are driven to their utmost to keep pace with the demand.

The quality of the water is also very far below what is

now considered a proper standard, the water being not only exceedingly turbid after storms, but also subject to serious sewage pollution. The typhoid rate of the city is unusually high, and this condition is no doubt chargeable, in great degree, to the sewage pollution at all times present in the water.

The deficiency of the supply, as to quantity, can be remedied by diminishing the waste, or by increasing the pumpage.

In many cases the supply to buildings is restricted by the lack of capacity of the distributing mains, but there are instances where, if the condition of these were improved, the draught would exceed the capacity of the pumping engines. We have elsewhere recommended the adoption of efficient measures for the reduction of the waste.

The defects in the matter of quality can be remedied either by abandoning the present sources of supply and adopting purer ones, or by applying to the water taken from the present sources well-known methods of purification.

Projects Specially Investigated.

The projects which we have investigated in detail may be grouped under two principal heads: Mountain waters, supplied in their natural state; and filtered waters, supplied from the Delaware and Schuylkill rivers.

The impounding or storage reservoirs may discharge directly into aqueducts or into the beds of the streams below them. In either case the water is received in other storage reservoirs further down stream, from which aqueducts convey it to the city.

Filtered vs. Mountain Water.

Where ample supplies of relatively pure water are obtainable at sufficient elevations and within short distances

of the community to be supplied, it will usually be found best to take advantage of them ; but where, as in our case, these sources are found at long distances from the city, it is necessary to estimate very carefully, and to balance still more carefully, the relative costs and advantages of different methods.

A gravity supply obviates the heavy operating expenses incident to a supply by pumpage, and thus naturally commends itself at first sight, but it may readily happen that the interest on the cost of construction of the gravity supply considerably overbalances the saving due to this consideration.

To utilize a gravity source of supply in our case requires not only the construction of long and expensive aqueducts, but also that of large and numerous impounding dams on the various small streams which would be taken as sources. These dams are necessary in order that the heavy winter and spring flows may be saved and made to compensate for the droughts of summer; thus regulating and rendering more nearly uniform the available yield of the stream throughout the year.

An advantage of the pumpage over the gravity system consists in this, that the former is capable of indefinite extension by small additions, whereas, when the capacity of an aqueduct has been fully taxed, a second one, usually of at least equal capacity, must be built.

In comparing the relative advantages and disadvantages of a mountain and a filtered water supply, it must be borne in mind that a filtered water supply is ordinarily susceptible of gradual and indefinite extension, as the demands upon it increase; whereas the construction of a gravity system, for a growing community, requires an outlay much in advance of requirements. It is true also that, owing to the greater length of time required for the construction of a gravity system, large sums of money

must be invested long before the system can be put into operation.

The adoption of any project for bringing mountain water to the city by gravity, at sufficient elevation to flow into our reservoirs, involves, of course, the abandonment of the pumping stations supplying these reservoirs.

In our own case, another consideration to be borne in mind is that the sums represented by the present value of the pumping plants would be lost in the case of the construction of a gravity supply.

In comparing the relative advantages of filtered and mountain water supplies, it is important to bear in mind the lengths of time which would probably be required for their installation. It is quite safe to say that the completion of all plants of any one of the slow filter systems herein suggested, could be accomplished within three years; whereas the construction of any of the mountain water systems would probably require not less than seven or eight years.

In bringing mountain water to the city, there would always be a question as to its absolute purity, because there is no guarantee against an accidental pollution. Nor is there a guarantee that the water, coming from territory sometimes densely covered with forests, would not, in the late summer, have a slight vegetal taste such as we find in most supplies from similar sources. In view of recent progress in the methods of water purification, and of the growing demand for better water, it seems not at all improbable that water procured from the Blue Mountains might in the future require filtration before being delivered to the city, thus adding materially to the expense of the project. The New York supply, although not coming from the mountains, is derived from a territory which is carefully protected against pollution, but it is an almost annual occurrence that, in

the summer, the water has a vegetal taste. A former Health Officer of New York City, Dr. Jenkins, is on record as saying that the New York water would no doubt eventually have to be artificially filtered in order to remove this taste and a slight turbidity.

Another advantage of a filtered water supply lies in the fact that, in case it should ever, in the future, be found necessary to change the source of supply—as, for instance, to abandon the Schuylkill and take filtered water from the Delaware—the loss in money would be less than if a mountain source had been used and a purification of such water had been found necessary.

In cases where the issue was doubtful, as to yield of water, or as to cost of construction and operation, we have, as a rule, given the benefit to the mountain water supply.

Quantity of Water Available.

As to the quantity of water obtainable from the sources at command under present conditions, it is self-evident that the minimum flow is all that can be relied upon throughout the year in any stream without reservoir storage, and the minimum flow usually occurs at a time of year when water is most needed.

Minimum Flow of Schuylkill.—On the Schuylkill river are a number of reservoirs which have been constructed by and which belong to the Schuylkill Navigation Company. The company uses these reservoirs for the purpose of supplying water for the maintenance of its navigation and for power at certain points. The City cannot depend upon the use of this impounded water to supply its need in time of drought, as the Navigation Company is under no legal obligation in this respect, although it has on several occasions acceded to the City's requests for assistance.

Various opinions have been given as to the extreme minimum flow of water in the Schuylkill river. After considering these we have decided that it would not be safe to rely upon taking from the river in times of drought, more than 150,000,000 gallons per day. This quantity may be less than the minimum flow, but even if the City had a plant for purifying the water, we do not consider it safe or proper to provide for using the entire flow, particularly at a time when the relative pollution of the river is greatest.

Yield of the Delaware River.—The Delaware river from its mouth to Trenton, N. J., is a tidal estuary. The minimum flow at the Water Gap, situated about 100 miles above Philadelphia, is estimated at about 700,000,000 gallons per day, only one-half of which, or 350,000,000 gallons per day, could be appropriated by the City of Philadelphia.

At this point it should be stated that while the City has the right to one-half of the flow, it has no right to cause injury to any of the riparian owners, resulting from a material lowering of the water level during a drought, the exposure of shoals, and the recession of the low water line from where it is at present. We have included in our estimates of cost no allowance for such damage, nor for diminishing any water-power rights below the intake.

Yields from Watersheds with Storage.—The upper Perkiomen creek comprises a drainage area of 120 square miles and, with storage reservoirs for which satisfactory sites exist, this source may yield a supply of 90,000,000 gallons per day.

The available safe yield of the Tohickon, the Big and Little Neshaminy creeks, according to the recent reports of the Water Bureau, are: Tohickon, 61,000,000 gallons per day, and Neshaminy, 83,000,000 gallons per day.

The upper Lehigh river drains an area of 377 square miles, while Big and Aquanchicola creeks, to the east of the river, south of Mauch Chunk, drain an area of 165 square miles. The watersheds of all these streams combined include 542 square miles, which, with storage, can be depended upon for a supply of 360,000,000 gallons per day.

The sources of the Delaware river above the Water Gap, from which good mountain water can be obtained, cover a drainage area of 430 square miles, and, with storage, will furnish 260,000,000 gallons of water daily.

Quantities available.—The quantities available, therefore, from the several sources mentioned are :—

Mountain Water, Unfiltered.

Lehigh river, including Big and Aquanchicola creeks	360,000,000 gallons per day.
Upper Perkiomen	90,000,000 " "
Sources near Delaware Water Gap	260,000,000 " "
Total	710,000,000 " "

Water Requiring Filtering.

Schuylkill river at Philadelphia	150,000,000 gallons per day.
Delaware river at Philadelphia	Practically unlimited.
Delaware river at Water Gap	350,000,000 gallons per day.
Tohickon and Neshaminy creeks, with storage	144,000,000 " "
Perkiomen creek above Schwenksville, with storage	160,000,000 " "

It is of course practicable to increase the minimum flow of the Schuylkill river by the storage of water on its affluents, particularly on the Perkiomen creek. As the pollution to which the water of the Schuylkill river is subjected will be greater, in spite of all legal restrictions, than the pollution of the Delaware river, which has a smaller resident population, we have deemed it rather

better to increase the city's supply by taking water from the latter stream, than by artificially increasing the minimum flow of the former. We have been guided in this decision also by the question of cost and by the existing rights of the Schuylkill Navigation Company.

Artificial Purification..

When water, to be used for a domestic supply, has become contaminated, it should be artificially purified by filtration, preceded by sedimentation where necessary. This method of purification has been in successful use in Europe for many years, and its use is growing in this country.

The investigations and experiments of the Massachusetts State Board of Health, which have extended over a number of years, have placed the subject of water puripurification upon a scientific basis, and it is possible now to effect any desired degree of purification with a certainty of results which, previous to such investigations, was impossible.

Water Filtration.

As we have already stated, it is rarely, if ever, that water obtainable in large quantities from natural sources can be used for domestic purposes in its natural condition with absolute safety. The very existence of such quantities of water generally involves the co-existence of a population more or less dense, with the corresponding certainty of more or less serious pollution ; and, even where a supply is normally of a high degree of purity, as in the oft-quoted case of Plymouth, Pa., we are never free from the menace of accidental and temporary pollution, such as decimated that unfortunate town. Hence, it is becoming more and more the conviction of water-supply engineers that proper regard for the health of the community de-

mands the artificial purification of all surface waters, however promising the sources from which they are drawn.

Nature's process of filtration in the production of spring and well waters has long been understood in a general way, and its artificial imitation, on a small scale, is probably as old as history itself. Within the last half century the same process has been extensively applied to the purification of the large volumes of water supplied to cities. London furnishes the most noteworthy example of this, and the system there adopted is still the one most generally employed.

In that system, the water is, if necessary, first allowed to remain at rest in sedimentation reservoirs, in order that it may free itself of its grosser mechanically suspended impurities, and is then allowed to filter slowly through beds of sand.

Until within a very few years, the sole function of this process seems to have been regarded as consisting in the removal of the mechanically suspended impurities and the consequent improvement in the *appearance* of the water; the turbid water of the Thames, for instance, being converted into a bright and sparkling liquid, probably quite as attractive in appearance, and as palatable, as the finest spring water; and it was freely conceded, even by the advocates of the process, that, in the language of an authority, the micro-organisms contained in the water "could pass a hundred or a thousand abreast through the interstitial spaces of ordinary sand as used for this purpose," and hence that "while filtration certainly clarified, it could not purify"—while it removed the visible dirt, "it could not remove the bacteria."

During recent years, however, the investigations of biologists and the sanitary results of filtration have clearly demonstrated its very important usefulness in the true purification and sanitation of the water—efficient filtra-

tion commonly removing 98, 99 and even more per cent. of the bacteria existing in the water.

The consequence of modern discoveries is a complete change in the accepted standard of purity of water. Whereas, previously, clearness and a satisfactory chemical analysis were considered sufficient evidence of wholesomeness, we now insist, also, that a certain permissible maximum number of bacteria—usually placed at 100 per cubic centimeter—shall not be exceeded.

Hence, while the science of filtration may be said to be still in its infancy, it cannot truly be said that "filtration is only an experiment."

One of the most striking instances of the efficiency of filtration in checking the spread of disease is the well-known case of Hamburg and Altona, in Germany. These cities, side by side on the banks of the Elbe, both take their water supplies from that stream, the Altona intake being placed below the point where the sewers of Hamburg discharge into the Elbe the sewage of nearly 800,000 persons. The two cities are practically one, the line of demarcation being, at most, a narrow street. In the winter of 1892–3, when the cholera visited Hamburg and when the deaths from that disease, in Hamburg, which used the Elbe water unfiltered, reached 1,250 per 100,000 of population, Altona, which used the same water filtered, had but 221 per 100,000. The boundary line between the two cities can be clearly traced, upon a map on which are plotted the cases of this disease, by the large number of such cases on the Hamburg side of the line, and their nearly complete absence on the Altona side. The few cases which appeared in Altona were generally traceable to the use of the Hamburg water, by transient visitors to the other city.

Filtration is found to remove, not only disease germs, but also the unpleasant vegetal taste which often charac-

terizes the water of small streams during summer and autumn.

It has also been well established that, in the system already mentioned, the sanitary work is done, not always directly by the sand itself, but, in the case of continuous filters, rather by matter deposited from the water upon and within the sand, which thus serves merely as a mechanical support for what may be termed the true filter, the deposit of "bacterial jelly," or, in German, the "*Schmutzdecke,*" which we may freely translate into "dirt-cover."

It is not to be supposed that all, or even most, of the bacteria found in ordinary surface waters, are hurtful. On the contrary, many of them are beneficent; and it is, indeed, upon the operations of these, that the biological processes of purification upon and within the sand filter largely depend; but it is practically impossible to discriminate between the beneficient and the harmful bacteria, and hence the removal of the hurtful or pathogenic bacteria, brought into the water by sewage pollution, requires that the depopulation of the water be made as complete as possible.

It is stated, upon good authority, that more than twenty million people in Europe are now being supplied with water filtered by slow-filters, and the number of persons thus supplied is annually increasing. The first filter of record appears to have been constructed about seventy years ago.

The slowness of operation of the system now being considered, requires an acre of ground space for every two or three million gallons filtered daily; so that, for a daily supply of 200 million gallons, from 70 to 100 acres would be required for the filter beds alone, in addition to that which might be required for the sedimentation basins.

To obviate the necessity for acquiring so much land,

American inventors have sought to take advantage of the method, known to the ancients, of using alum or some other coagulant, to hasten the formation of the true filtering medium, as well as to expedite, in other ways, the entire process.

Besides, the "*Schmutzdecke*" sometimes requires several days for its formation, and, during this time, the water is but imperfectly filtered, and should be allowed to run to waste. Again, the filters naturally become clogged with sediment, and require cleansing usually every few weeks, and this cleansing is a slow process, throwing the filters out of use for a still further time.

The result of these efforts is the so-called "mechanical" filter, which consists usually of a tank, from ten to twenty feet in diameter, and containing a sand filter bed. Either at or prior to its admission to the filter, the water receives a small quantity of alum, or other coagulant, the proper behavior of which depends upon the presence, in the water, of some base, such as lime. This base unites with the sulphuric acid of the coagulant, thus setting free the alumina, which, in the form of aluminum hydrate, settles slowly through the water, carrying down with it much of the impurity of the water, while the new sulphate formed by this process is deposited with it.

Another distinguishing feature of the "mechanical" process consists in the arrangement for cleansing the filter. This consists (1) of a set of rakes, set in revolutoin by machinery when required (whence the term "mechanical") and (2) the reversal of the normal current of water, the water already filtered being forced backward through the bed, not only facilitating the revolution of the rake, but carrying with it most of the impurities deposited upon and within the bed by the water previously filtered.

For convenience, we apply the term "slow" to the system first described, and represented most prominently by the great filter beds of London, Berlin and Hamburg, and sometimes called the "English" system; and the term "rapid" to the so-called "mechanical" or recently called "American" type of filter. Our reason for selecting the terms "slow" and "rapid" is that they designate the most important distinguishing feature. The former system allows from 6 to 12 cubic feet, the latter from 200 to 300 cubic feet of water daily to pass through one square foot of filter surface.

By virtue of some operation not yet thoroughly explained, rapid filters appear to be able to secure equally as satisfactory bacteriological results as the slow filter, although filtering at from thirty to fifty times the rate. In other words, for a quantity of water requiring from thirty to fifty acres of filter beds by the slow process, one acre of surface of rapid filters would suffice, provided the conditions of the given case were equally favorable to the two systems.

It is now generally recognized that, as a rule, the slow system is best adapted to waters containing relatively little suspended matter, although they may be highly polluted by sewage, and the rapid system to the treatment of highly turbid but less seriously polluted waters, or in those cases where, as in certain manufacturing processes, clearness is the first consideration, and wholesomeness of less or no account. As a matter of course, the rapid filter commends itself especially for those cases where suitable ground for the large slow filter bed is not practically available.

The functions of the rapid filter, however, are by no means confined to the mere clarification of the water. It is also a very efficient purifier. Hence, it has found extensive and successful application, especially in this coun-

try, for the purification of the water supplies of towns and cities. In these cases, usually a considerable number of the filtering tanks, or "units," are installed side by side, in connection with suitable machinery for operating the revolving rakes, and with appliances for the admixture of the coagulant and the regulation of its quantity.

Where lime, or its equivalent, is deficient in the water in its natural state, it must be added artificially, in order to insure the necessary decomposition of the coagulant.

We have already given the results of investigations to determine the effects of the use of coagulants upon the wholesomeness of water and upon their availability for use in boilers.

The hardness of the Schuylkill water adapts it to the use of the rapid system, with its necessary employment of coagulants, the lime in the water acting favorably in the decomposition of the coagulant, and it is our opinion that the use of the coagulant would not materially, if perceptibly, increase the hardness of the water. With slow filters, a coagulant would be used only when the river runs very muddy, as happens only occasionally even with the Schuylkill water; and we doubt whether it would ever be required with the much softer and less turbid water of the Delaware.

If precisely the proper quantity of coagulant could be applied, it would all be decomposed, and all of the lime in the water would unite with all of the sulphuric acid of the coagulant. Hence, none of the coagulant could pass out with the filtered water. The only effect, in this respect, would probably be the diminution of the "temporary" hardness (that due to carbonate of lime) and an increase of the "permanent" hardness (that due to sulphate of lime).

The maximum quantity of sulphate of alumina used in the rapid filter rarely exceeds two grains per gallon,

and it is often much less. The Rhode Island Board of Health, for instance, has stated that 0.6 grain per gallon is sufficient.

Sedimentation in reservoirs is accomplished in two ways. In one of these the water is allowed to pass through the basin continuously; in the other it is admitted and drawn off intermittently. By the continuous method, the water enters at one side of the basin, and its velocity very greatly decreases as the water flows to the other side, whence it is drawn off near the surface. The reduction of velocity permits the gross particles of suspended matter to subside. By the intermittent method the water enters the reservoir generally with a greater velocity than in the continuous method, but it is then shut off, comes practically to rest, and remains at rest for a sufficient time to allow the suspended matter to settle. The clear water is then drawn off. Both methods have their advantages and disadvantages; and, in the lack of sufficient information regarding the quantity of suspended matter in the water furnished to this city throughout the year, it is impossible to say which of the two methods would be the better one to use in this city. The estimates of cost presented are, however, in our opinion, sufficiently liberal to cover approximately either case.

In the case of the Schuylkill river water, and when settling reservoirs are used for its preliminary treatment, it may be necssary to add alum to the water at times when suspended matter is in very large amount or when it is very fine. Our opportunities of observation do not enable us to state to what extent such a treatment would be necessary in the case of Philadelphia, but we think it would hardly be necessary on more than from ten to twenty days in the year.

In the case of slow filtration, the use of a coagulant would be found advisable, only during, or just after,

heavy freshets. At such times the amount of alkaline sulphates naturally in the water are approaching a minimum, the organic matter being then most diluted. Any increase in these sulphates due to the decomposition of the natural carbonates by the use of sulphate of alumina, would in all probability not make the total percentage of alkaline sulphates as high as during a drought, when it approaches a maximum. The use of a coagulant during freshets, therefore, could make no appreciable difference in the quality of the water.

Filter Plants and Various Projects Examined.

Sundry methods of filtration, purification, sterilization, etc., have been presented to us for examination, and a hearing has been given to those proposing or suggesting them.

Wilmington Filter.—A visit was made to the water purification plant at Wilmington, Delaware. The system there adopted is based on a treatment of the water with iron, a subsequent thorough aeration and an upward filtration through a bed of 20 inches of gravel and 18 inches of sand. There are five filter beds in use, each 16 by 125 feet, filtering at a daily rate of over 40,000,000 gallons per acre (about 133 cubic feet per square foot) per day. The ordinary cleaning of the beds is accomplished by reversing the current and washing the material in place with both air and water.

The iron treatment is secured by means of a series of revolving bundles of small iron rods, suspended transversely in a long trough through which the water flows. A small portion of the iron is removed by attrition and oxidation, and acts like the iron used in the Anderson process. No repeated analyses of the water had been made before and after this treatment, and no data were available to establish its real efficacy. This fact, and the

lack of success of the similar Anderson process, rendered a further investigation inadvisable.

Albany Filter.—We next visited the new filter plant at Albany, N. Y., designed by Mr. Allen Hazen. At that time it was not quite completed, but it has since been put into operation. It is the largest filter plant now in use in the United States. It consists of an open sedimentation basin holding 16,000,000 gallons, and 8 filter beds, each 0.7 acre, with a total area of 5.6 acres, and a total filtering capacity of about 15,000,000 gallons per day, being at the rate of about 3,000,000 gallons per acre (about 9 cubic feet per square foot) per day. The filter beds are covered with groined concrete arches; and all appurtenances necessary or advisable for effective operation, such as regulators to control the rate of filtration, sand washing apparatus, a bacteriological laboratory, etc., are provided. The filters have apparently been built with great care and excellence. The filtered water is pumped into an uncovered distributing reservoir in the western part of the city.

Poughkeepsie Filter.—We also visited Poughkeepsie, where a filter plant has been in existence for more than 27 years and is still in active use, filtering about 1,600,000 gallons per day, or, with a population of 23,000, about 70 gallons per capita.

This plant was designed and erected under the supervision of the late James P. Kirkwood, who had investigated the filtration systems of Europe in the interest of the City of St. Louis, Mo. It is located on the east bank of the Hudson river and the original plant comprises a settling basin, 25 by 50 feet by 12 feet deep, a filtering basin, 150 by 200 feet by 12 feet deep, and a filtered-water basin, 28 by 88 feet by 17 feet deep, with an intermediate chamber, 6 feet by 88 feet by 16 feet deep. The filtering materials are 24 inches of coarse broken stone,

24 inches of gravel of varying sizes and 24 inches of sand. The filtered water is pumped up to a large uncovered distributing reservoir on a hill back of the city. This reservoir has a capacity of 12,000,000 gallons or about 7 days' supply.

In 1896 an additional filter was constructed, doubling the capacity of the plant. It is fed from the old settling basin, the water discharging into a delivery well and thence to the old filtered-water basin.

All of the basins are uncovered, except that for filtered water, which also was originally open. So much trouble was experienced from the growth of algæ that in 1891 it was covered, and it has since given no further trouble. The fact that the filters are uncovered has caused much difficulty in operating them. In summer the growth of algæ at times almost stops their action, and in winter the frost causes difficulty in cleansing the beds and keeping them in proper working condition.

On account of the expense an attempt was made, in 1874, to substitute simple subsidence in the distributing reservoir, but after a trial this was abandoned. The annual report of 1878 states that "the consumers accustomed to drink filtered water will accept nothing else, nor will they consider any circumstances or complication of circumstances as offering any excuse for the non-use" of the filters.

We were informed that the filters are operated only for three or four days in the week. The rate of filtration was about 4,500,000 gallons per acre (about 14 cubic feet per square foot) per day, until the construction of the additional filter in 1896. With the latter in use, the rate is now about 2½ to 3 million gallons per acre (about 9 cubic feet per square foot) per actual day of operation. The filters are usually cleaned at intervals of from one to five weeks, but sometimes not for two months, depending upon

the condition of the raw water, the accumulation of algæ, etc. With good management, the plant seems to have produced satisfactory results, even under adverse conditions.

Reading Sewage Filter.—During our investigation of the Schuylkill region, we made an examination of the sewage filtering plant at Reading, erected under the patented system of Mr. John Jerome Deery, President of the Pennsylvania Sanitation Company, Mr. Deery having presented plans for filtering the water of Philadelphia by the same method.

The plant has been in operation about three years. It is designed to act first as a strainer, then as a filter, passing, as we understand, about 10,000,000 gallons per acre per day. Much reliance is placed upon aeration and sunlight to purify the water. Repeated examinations of the filtrate at Reading since the plant has been in operation, revealed faint sewage odor and color. The process as proposed for Philadelphia would not by itself yield a safe drinking water, if judged by established principles and the results of experience.

Maignen Filter.—Our attention was called to the Maignen method of water purification, and a special examination was made of a model plant of experimental filters in operation.

The new and special feature of the Maignen system is the use of an asbestos film resting on top of the sand of the filter bed, to take the place and perform the useful office of the dirt cover (*Schmutzdecke*) on the bed of the ordinary filters, in retaining bacteria.

The water passes through Mr. Maignen's experimental filters at the rate of about 10 to 12 million gallons per acre (about 30 to 37 cubic feet per square foot) per day. It is clear, and, according to the analyses made by the chemist of the Company, also nearly free from bacteria. It is stated that in all the examinations made of

the effluent water, the bacteria have never been found to exceed one hundred to the cubic centimeter, the standard limit adopted by the German Imperial Board of Health.

While the models show good results, and while the treatment of the problem has been carefully considered by the inventor, experiments have indicated the existence of a troublesome feature, in connection with the asbestos film, due to the collection of air bubbles below the same and a consequent interference with the required percolation of water. A remedy has been suggested by the inventor, but, until the system has been successfully used on a sufficiently large scale, we cannot recommend it for the City of Philadelphia. It could, however, at any time be readily added to any of the usual slow filtering plants, if its usefulness were established, and thus obviate their otherwise necessary areal extension *pari passu* with the growth of the city.

New York Filter Manufacturing Company.—A conference was held with the New York Filter Manufacturing Company, represented by Messrs. Samuel L. Morison, General Manager, and Edmund B. Weston, Consulting Engineer, to consider the method of filtration employed by that Company, and the cost of constructing and maintaining such a plant.

This Company uses a system of rapid filtration, the rate being 100,000,000 gallons per acre (about 300 cubic feet per square foot) per day. They claim to have made an advance in their latest apparatus, by joining the compartments for sedimentation and filtration in such a way that they can dispose of from 75 to 80 per cent. of impurities by sedimentation, before the water reaches the filter. The water is first treated with a coagulant (sulphate of alumina) and then passed through a settling basin, where it is subjected to a rotary movement which

hastens the precipitation of the hydrate of alumina and other matter in suspension; thereby shortening the necessary time for sedimentation, and obviating the use of much larger settling basins.

A design for a unit filter was shown us, consisting of a cylindrical tank, 26 fect outside diameter, and appurtenances, giving an inside filtering area of 452 square feet. The water is first treated with the required amount of sulphate of alumina from a supply tank by means of an automatic feed, known as the old Warren Chemical Feed, which secures the delivery of a quantity of alum in exact proportion to the quantity of water entering the filter, and which is provided, also, with means of regulation to meet the requirements of the varying character of the water.

Having received the proper amount of this coagulating solution, the water enters a lower basin in the bottom of the cylindrical filter tank in a tangential direction through a deflecting elbow. This gives it a rotary motion about the centre of the tank, which motion materially facilitates coagulation. When filtering at the rate of 100,000,000 gallons per acrė (about 300 cubic feet per square foot) per day, the water is detained in this lower basin for the period of about one hour, although in continuous passage to the filter bed above. During this time a large amount of the small particles of matter in suspension, with bacteria, etc., are gathered together in larger masses, many of them being of sufficient weight to fall to the bottom of the settling tank, about 75 per cent. of such matter being removed. The fresh supply tends to the outer edge of the tank by the centrifugal force due to rotation, and the water remaining longest under the action of the coagulant gradually reaches the centre. The water is then fed from the centre of the tank by an upright central pipe to the filter bed above.

The water is distributed upon the filter, and deposits thereon matter remaining in suspension, together with the lighter particles of hydrate of alumina not already deposited in the settling tank below. The water passes through the accumulating film, and then through four feet of sand to the screen system. There are about 1800 separate screens, made of aluminum bronze, laid as a pavement on the floor of this upper tank to prevent the sand from escaping. Through these screens the water passes to a central manifold, and then to the controller.

The controller, designed by Mr. Weston, is one of the most important improvements in this type of filter.

A filter bed, when clean, operates more rapidly than after it becomes clogged with deposit, the speed becoming less and less until a condition is reached when washing is required. The controller regulates this speed automatically, determining the number of gallons per minute that shall pass through the filter, and thus making its action uniform. When a certain height of water is reached and the available friction head has been entirely consumed, the sounding of an automatic signal shows that the time for washing has arrived.

To wash the filter, clear water is pumped back through the pipes leading to the screens in such quantities as to give an upward velocity through the sand about three times as great as the velocity of filtration. It raises the entire bed in the form of quicksand, leaving the sand grains completely in suspension. At the same time a mechanical agitator is started, consisting of a series of iron rods suspended from arms revolving over the filter bed. The rods penetrate the bed nearly to the bottom. This facilitates the loosening of foreign matter in the bed, and both this matter and the wash water are carried off over the edge of the tank forming the filter proper, down the annular space between this and an outside tank, and thence to the sewer.

Information was given us as to the experience of this filter company in treating Schuylkill and Delaware river waters. Private filter plants of their installation were mentioned, of which three were on the Delaware river connected with sugar refineries and one of 5,000,000 gallons on the Schuylkill river.

Sterilization by Boiling.—Our attention was called, by Mr. John Forbes, of the Waterhouse-Forbes Company, to an ingenious method of sterilizing water by boiling. By a simple contrivance, two vertical currents of water are kept flowing past each other in contiguous passages, so that their heat is equalized by convection. The water, upon reaching the top of one column, is heated to the boiling point, and then, in descending, gradually imparts its heat to the water rising in the first column, and finally escapes with a temperature only 2 to 5 degrees higher than the original temperature of the water. The water is thus actually boiled with a very small expenditure of heat. In our judgment, this process, irrespective of financial reasons, falls short of solving the question before us, inasmuch as it does not remove the turbidity of the water.

Recent Reports on Filtration Experiments.

Reports have recently been made by Filtration Commissions of Louisville, Cincinnati and Pittsburgh, containing the results of investigations and experiments which have been valuable to us. The character of the waters of the Schuylkill and the Delaware rivers is not necessarily the same as that of the waters of the Ohio and Allegheny rivers. The latter vary considerably in quality, but there is much that is common to all river waters. As it was impossible, within the limited time at our disposal, to undertake any investigations with experimental filters at Philadelphia, desirable as it would have been, we were obliged to depend largely upon experience gained

elsewhere, and we have taken all possible advantage of the above mentioned reports.

The investigations at Louisville and Cincinnati were reported by Mr. George W. Fuller, Consulting Expert, and those at Pittsburgh by Mr. Allen Hazen, Consulting Engineer, with Mr. Morris Knowles, Resident Engineer. Reference must be made to the reports for details.

Louisville.—At Louisville seven different types of filters were investigated: the Jewell, the Warren, the Western gravity, the Western pressure, the Harris magneto, an electric system, Palmer and Brownell water purifier, and the MacDougall Polarite system. Daily tests were made from October 21, 1895 to August 1, 1896.

The area of 85,000 square miles, comprised within the water-shed of the Ohio river, exhibits wide extremes in geological formation. The population above Louisville is 4,500,000, of which 1,575,000 are in 220 towns and cities, with an increase of 15 per cent. in six years. With great and rapid changes in the character of the river water, depending upon the section of country from which freshets come, (and these freshets are occasionally very heavy,) the problem was not a simple one. At no time is the water entirely clear. The ratio between maximum and minimum weights of suspended matter was found to be as great as 5311 to 1, and the color varied from light grey to dark red. As a rule the water had a slight odor, which, however, was occasionally quite pronounced, in fall and spring musty, sometimes aromatic and resinous. In spring after rains it had a vegetable odor. The sediment consisted at times of large amounts of fine particles of silt and clay, requiring weeks to settle. Individual particles were sometimes as small as 0.00001 inch in diameter.

Mr. Fuller states, in his general conclusions, that "it is proved conclusively that the general method embodying

subsidence, coagulation and filtration is most suitable for the proper and economical purification of the Ohio river water at this city (Louisville). With regard to the use of coagulants, it may be stated in unqualified terms that their use is imperative for this water, because for at least six or ten weeks in the spring and early summer, the Ohio river water contains such large quantities of fine clay particles, many of which are smaller than bacteria, that clarification and purification without coagulation would be impracticable if not impossible."

Further investigations were conducted from April to July, 1897. In the final summary and conclusions there are some points that may here be noted. When the water is high and muddy it is not specifically injurious. When it is low and comparatively clear it is most to be feared. Filtration, preceded by subsidence, is the correct method, and the use of coagulants is imperative.

An effluent water, free from turbidity, could be secured with an English (slow) filter plant at a net rate of about 1.5 million gallons per acre ($4\frac{1}{2}$ cubic feet per square foot) daily, but there was a marked indication that fine clay was passing into the sand-layers, necessitating a cleansing at frequent intervals. A preliminary subsidence was necessary, and sulphate of alumina was found to be the most suitable coagulant. There were times when coagulation, in conjunction with subsidence, could be employed to advantage. The experiments with American (rapid) filters indicated that by taking advantage of a preliminary subsidence, the amount of sulphate of alumina could be held at from 1.5 to 2 grains per gallon, with an annual average of 1.75 grains.

With regard to the use of water in steam boilers, from filters using a coagulant, more incrusting constituents were found than in the raw river water, although their annual average amount contained in the filtered water was only

about 60 per cent. of the quantity normally present in the river water during the fall months. The effect of adding coagulant would be largely if not wholly offset by the removal of the suspended matters. Compared with the waters of other cities, that of Louisville would be classed as a satisfactory boiler water.

Cincinnati.—Mr. Fuller's investigations at Cincinnati are of later date. He says: "This work had for its object an investigation in the practicability of the method proposed by the Engineer Commission of 1896, by which, as a part of the extension and betterment of the municipal water supply, the Ohio river water should be partially clarified by plain subsidence for several days and then filtered, as suggested, through filters of the English type." "Owing to the fact that the Ohio river water at Cincinnati differs materially in its character for about six months in the year from those waters where this method of purification has long been successful, it was recommended both by the Board of Expert Engineers of 1896 and the Chief and Consulting Engineers of the present Board that, before proceeding further, sufficient reliable data should be obtained with reference to the exact local conditions." Experimental filter plants were erected and operated, chemical and bacterial analyses were made, weight of suspended matter determined in special samples, etc., etc.

"Specific difficulties and complications in the treatment of the local river water by plain subsidence and English filtration" were encountered and there were "features wherein plain subsidence for three days and English (slow) filtration failed essentially in the clarification and purification."

To prolong the average period of plain subsidence "beyond about three days would not be practicable on the ground of cost." The use of coagulants was therefore found to be imperative at certain periods on account

of the fine clay particles contained in the water. Mr. Fuller further states that "so far as present knowledge upon this subject goes, there is only one way in which these clay particles can be removed, and that is to apply a chemical which shall aggregate them into flakes or masses, so that it is practicable to remove them subsequently by subsidence and filtration."

To assist the process of filtration at times of heavy freshets, a coagulant was introduced into the settling basins "only when economical provisions for plain subsidence are incapable of preparing the turbid water adequately for filtration, and in such amounts that the water going upon the English (slow) filters may be properly and readily filtered." He found it essential to allow the coagulated matters suspended in the water to subside in the settling basins so that they would not rapidly close up the pores of the sand layer at the surface. "That is to say, the water applied to the English (slow) filters must be substantially free from coagulated masses of clay."

Mr. Fuller finally concluded that "it is practicable to clarify and purify the Ohio river water in a satisfactory manner by either the modified English system (slow filtration with accelerated sedimentation) or by the American (mechanical or rapid) system." He recommends the adoption of the latter system as "somewhat cheaper," and giving substantially the same quality of filtered water. This decision is of course based on local conditions.

Pittsburgh.—A report upon the investigations made by the Pittsburgh Commission was issued in January last. Personal visits were made by its members to the experimental plants at Louisville and Cincinnati and several of the members also visited filter plants in Europe.

The City of Pittsburgh is supplied with water from the

Allegheny and Monongahela rivers, principally from the former, and the water is objectionable on account of the mud it carries and because of its pollution by sewage. "Elaborate experiments extending over a period of time of sufficient length to show the effect of filtration upon the water of the Allegheny river in all seasons and at all stages" were carried on, and it is stated in the report that the "investigations show the entire feasibility of so treating the water by several methods as to remove both the mud and the deleterious vegetable growths contained therein."

Of the various methods of filtration examined, "two have proved themselves efficient, the method of mechanical (rapid) filtration and the method of sand (slow) filtration" "The latter has yielded upon the whole somewhat better results than the former." "As is fully put forth in the report of the Experts employed by the Commission, etc., the method of sand (slow) filtration not only yields a supply of water free from mud and objectionable bacterial life, but also furnishes a supply of water of a quality adapted to mechanical purposes, suited to the uses of industrial establishments." These conclusions, like those reached in Cincinnati, are based on local conditions.

The use of meters was also investigated and strongly recommended, it having been concluded, after careful investigation, that the city was wasting "more than twice as much water" as it had any use for.

The Pittsburgh Commission had special experiments made to determine the adaptability of filtered water to use in boilers. It was originally intended to experiment at the city's pumping station, but difficulties occurred in regard to this, and three new 25-horse-power boilers were loaned to the Commission. These were operated respectively with the effluent from the sand

filters, with the effluent from the mechanical filters and with unfiltered river water. The report states that the boiler using unfiltered river water was found in the best condition, and, although considerable scale and sediment were deposited, the deposit was soft, adhered loosely and could easily be washed off and removed. The other boilers showed about the same results, although, in the one in which water from the mechanical or rapid filter was used, the rivets were badly corroded and a thicker incrustation formed in the tubes than in the one taking its water from the slow filter.

Regarding all the methods of purification, the report concludes "that filtration of the Allegheny river removes the mud and insoluble matter which would, by depositing, cause the boilers to be frequently cleaned and washed out. The incrusting properties which remain, while they may not make scale as quickly or as thick as if greater amounts of other material (mud, etc.) were present, yet, when the deposit is formed, it is hard, of a character which gives it the name of 'porcelain scale,' and difficult to remove except by tools."

Filtration is no longer an experiment. All filter works, so far constructed and properly operated, have demonstrated their efficiency beyond any question.

In comparing the slow with the rapid filter, it should be borne in mind that any accidental disturbance in the process of filtration is likely to interfere with the purification of the water nearly in proportion to the rate of filtration.

Projects Presented.

We present, for your consideration, several projects for the radical improvement of the entire water supply of the city, viz.:

A.—200,000,000 gallons daily of mountain water, from

the tributaries of the Upper Lehigh and from the Upper Perkiomen, delivered by gravity into Queen Lane reservoir.

An 8-foot aqueduct, extending from Big creek, on the Lehigh river, to Treichlersville, on the Upper Perkiomen, carries the impounded waters of the Upper Lehigh tributaries into one of the reservoirs on the Perkiomen creek.

A dam at Green Lane, on the Perkiomen, impounds the combined waters of the two streams, which are carried thence by a 12-foot high-level aqueduct to the Queen Lane reservoir.

B.—200,000,000 gallons daily of mountain water, from the tributaries of the Upper Delaware, near the Water Gap, delivered by gravity into a new reservoir to be constructed near Twelfth street and Olney avenue.

A 14-foot aqueduct extends from the Delaware Water Gap to the proposed new reservoir at Twelfth street and Olney avenue, conveying thereto the impounded waters of the Upper Delaware tributaries, which it receives through several feeders at the Water Gap.

C.—450,000,000 gallons daily of mountain water, from the tributaries of the Upper Lehigh, and from the Upper Perkiomen, delivered by gravity into Queen Lane and East Park reservoirs.

The Lehigh aqueduct extends from White Haven, on the Lehigh, to Treichlersville, on the upper Perkiomen, and the combined waters of the Lehigh tributaries and of the upper Perkiomen are carried from the impounding reservoirs at Green Lane through a 12-foot high-level aqueduct to Queen Lane reservoir, and through a 12-foot low-level aqueduct to East Park reservoir.

D. 450,000,000 gallons daily of mountain water, viz.: 225,000,000 gallons delivered by gravity from the tributaries of the upper Delaware, near the Water Gap, into the new Olney avenue reservoir, and 225,000,000 gallons

delivered by gravity from the tributaries of the upper Lehigh and from the upper Perkiomen, into Queen Lane reservoir.

The 14-foot Delaware aqueduct extends from the Delaware Water Gap to the Olney avenue reservoir, as in Project B, and the 8-foot Lehigh and 12-foot high-level Perkiomen aqueducts extend from Big Creek, on the Lehigh, to Queen Lane reservoir, as in Project A.

E. 700,000,000 gallons daily of mountain water, from all of the above-named sources, delivered by gravity into the new Olney avenue reservoir, into Queen Lane reservoir and into East Park reservoir.

This project, forming, in fact, a combination of the preceding projects, is suggested merely to indicate what provision may be made in case the consumption of water should continue increasing as it has done in the past. But, if proper precautions are adopted to prevent unnecessary waste, so large a quantity as 700,000,000 gallons daily will not be required even fifty years hence. Indeed, it is likely that 450,000,000 gallons per day will meet all requirements at that time.

F. 200,000,000 gallons daily, of filtered Schuylkill and Delaware river water, from slow filter at Torresdale, Queen Lane, Roxborough and Belmont and from rapid filters at East Park, delivered by pumpage into existing reservoirs.

The Delaware water filtered through slow filters at Torresdale, and the Schuylkill water filtered through slow filters at Roxborough, Queen Lane and Belmont, and through rapid filters at East Park, is pumped into the existing reservoirs.

G. 450,000,000 gallons of filtered Schuylkill and Delaware river water daily from the same system enlarged.

H. 450,000,000 gallons of Delaware river water daily, filtered by rapid filters at Portland, and delivered by gravity into the new Olney avenue reservoir.

*Mountain Water Supply.**

Source.	Daily Supply. Gallons.	Cost of Aqueducts, storage, etc.	Cost of Distribution to City Reservoirs.	Total Cost.	Annual Cost of Operation and Maintenance.	Cost per Thousand gallons. Cents.
per Perkiomen creek and Lehigh river tributaries	200,000,000	$32,090,000	$1,320,000	$33,410,000	$1,205,000	1.65
per Perkiomen creek and Lehigh river, with tributaries	450,000,000	64,590,000	2,150,000	66,740,000	2,480,000	1.51
laware river tributaries near the Water Gap, Upper Perkiomen creek and Lehigh river tributaries	450,000,000	78,630,000	4,555,000	83,185,000	2,925,000	1.78

Slow Filter Supply.

Source.	Daily Supply. Gallons.	Cost of Filters and Accessory Works.	Cost of Mains to connect Torresdale plant with East Park Distribution System.	Total Cost.	Annual Cost of Operation and Maintenance.	Cost per Thousand gallons. Cents.
,000,000 gallons daily from the Schuylkill river; 50,000,000 gallons daily from the Delaware river........	200,000,000	$9,453,591 05	$1,520,000 00	$10,973,591 05	$1,227,373 35	1.68
,000,000 gallons daily from the Schuylkill river; 300,000,000 gallons daily from the Delaware river........	450,000,000	23,174,691 51	10,980,000 00	34,154,679 51	2,971,801 26	1.81

Rapid Filter Supply.

Source.	Daily Supply. Gallons.	Cost of Filters, Aqueducts and Accessory Works.	Cost of Distribution to City Reservoirs.	Total Cost.	Annual Cost of Operation and Maintenance.	Cost per Thousand Gallons. Cents.
,000,000 gallons daily from the Delaware river, filtered at Portland........	450,000,000	$62,542,747 00	$5,320,000 00	$67,862,747 00	$3,239,379 21	1.97
,000,000 gallons daily, mountain water from storage above Water Gap and 190,000,000 gallons daily from the Delaware, filtered at Portland........	450,000,000	73,325,052 00	5,320,000 00	78,645,052 00	3,170,805 46	1.93
,000,000 gallons daily from the Delaware, filtered at Torresdale........	450,000,000	15,798,376 00	6,120,000 00	21,918,376 00	3,108,606 00	1.89

* The cost of delivering 700,000,000 gallons daily of mountain water into the city reservoirs would be $116,585,000, and the annual expense of operation and maintenance would be $4,310,000.

The rapid filters at Portland are supplied with water pumped at that point from the Delaware river, the supply of which, in dry seasons, is to be augmented by a maximum of 100,000,000 gallons daily of impounded mountain water from the tributaries of the upper Delaware near the Water Gap. Two 12-foot aqueducts carry the filtered water from Portland to the new reservoir near Olney avenue.

J. 450,000,000 gallons daily of Delaware river water, filtered by rapid filters at Torresdale, and delivered by pumpage into existing reservoirs.

The rapid filter plant at Torresdale is supplied with Delaware river water pumped at that point. After filtration the water is pumped to existing reservoirs.

K. 450,000,000 gallons of water daily delivered by gravity into the new Olney avenue reservoir, viz:—190,000,000 gallons of Delaware river water taken and filtered by rapid filters at Portland, supplemented by 260,000,000 gallons of mountain water brought to Portland by gravity from tributaries of the Delaware river near the Water Gap.

The rapid filter plant at Portland is supplied with 190,000,000 gallons daily, pumped from the Delaware at that point, and the filtered water delivered into the aqueducts there is supplemented by 260,000,000 gallons daily of mountain water brought from the tributaries of the upper Delaware through an aqueduct.

Two 12-foot aqueducts carry the combined mountain water and filtered Delaware water to the new reservoir near Olney avenue.

The costs of construction, operation and maintenance of these various projects are set forth in the table opposite.

Mullica River Project.—In addition to the Schuylkill and Delaware rivers and their tributaries, attention was drawn to another source, viz.: a locality some thirty miles

southeast of Camden, in the State of New Jersey, comprising the area drained by the Mullica river and its branches, and of this some investigation was made.

This source appears to offer peculiar advantages in some respects, namely: contiguity to the city, abundance and comparative purity of the water, with but little danger of pollution in the future, and reasonableness in the cost of constructing the works. But the acquisition of the right to draw upon this water supply in another state would require legislation, and this would certainly involve considerable delay, if, indeed, the necessary authority could be obtained at all; a matter which, in the opinion of the Law Department of the city is, at least, doubtful. In the event of adverse action, the whole question of water supply for your city would revert to its present status, with nothing accomplished. We, therefore, abandoned the consideration of the subject.

The method to be adopted for distributing the water into the city's reservoirs will depend upon the amount required, and also upon whether it is brought from the mountains or is taken from the Schuylkill and Delaware rivers near the city.

If the water is brought from the Perkiomen and Lehigh watersheds, it can be delivered by gravity into Queen Lane reservoir (238 feet above city datum), and into all the other reservoirs of the city, excepting those at Roxborough and Mount Airy, into which the water must be pumped. For the present consumption it would be necessary to build but one aqueduct from the Lehigh watershed into the Perkiomen valley, and thence to the city. A consumption of 450,000,000 gallons daily would require the building of another aqueduct, from Perkiomen creek to the city, which would deliver its water into East Park reservoir.

If the water is brought from the Delaware Water Gap,

it would be delivered by gravity into all the reservoirs of the city, including a new one proposed near Olneyville, excepting the Queen Lane, Roxborough, and Belmont reservoirs, into all three of which the water would have to be pumped from the level of the aqueduct (170 feet above city datum).

If the water is obtained near the city from the Schuylkill and Delaware rivers, it will require pumping into all of the reservoirs.

Mountain Water Supplies.

In our estimates of gravity supplies we have given preference to aqueducts of masonry, where these were practicable. In other situations, such as the crossings of deep valleys, we resort to the use of steel pipe. Where mountains or hills are encountered, tunnels are frequently necessary.

Where steel pipes are used, it is preferable to lay several of smaller size side by side rather than to use one large pipe of nearly equal cross-section, because, in the former case, the result of a break is far less disastrous.

The building of a gravity or aqueduct system involves the construction not only of intakes and gatehouses where the water leaves the reservoirs, but also of gate-houses at different points, with arrangements for shutting off, upon occasion, any portion of the pipe.

The Delaware river aqueduct begins at the mouth of the Bushkill creek, Pike county, follows the western side of the Delaware river as far down as Point Pleasant, and thence takes the most available course to the city. It collects the water from the various mountain creeks, which is to be stored in large reservoirs to equalize their yearly flow.

The Lehigh-Perkiomen aqueduct begins at White Haven on the Lehigh river, follows this river down to

near Slatington, and thence takes the most direct course to the Perkiomen watershed, which it reaches through a tunnel terminating near Treichlersville. It collects the water from the upper Lehigh river and from several mountain creeks, the water of which is stored in large reservoirs for equalization. These waters mingle with those of the watershed, and together they are taken into two aqueducts at Green Lane, one being a high-level and the other a low-level aqueduct, which convey the water to the city.

The following plates illustrate the projects for mountain water supply:

Plate I. Plan of watersheds of Delaware and Lehigh rivers, and Perkiomen and Tohickon creeks, with aqueducts.
Plate II. Profile of Delaware aqueduct, Water Gap to Kintnersville.
Plate III. Profile of Delaware aqueduct, Kintnersville to Philadelphia.
Plate IV. Profile of Lehigh aqueduct, White Haven to Aquanchicola creek.
Plate V. Profile of Lehigh aqueduct, Aquanchicola creek to Treichlersville.
Plate VI. Profile of Perkiomen high-level aqueduct.
Plate VII. Profile of Perkiomen low-level aqueduct.
Plate VIII. Typical aqueduct sections.

Filtered Water Supplies.

The slow filters are all designed for an average rate of 3,000,000 gallons of water per acre of effective area (about 9 cubic feet per square foot) per day. The number of filter beds erected at each site at first would be only for present demands, and each plant could be increased thereafter from time to time, as found necessary, by additional filter beds,

ample ground having been reserved for this purpose, except in the case of the Queen Lane.

The area available for slow filters at Queen Lane is limited, so that provision cannot be made at that site to filter more than 58,000,000 gallons per day, although the amount used in that district will hereafter be considerably greater. This deficiency will be made up from East Park, and for that purpose high-service pumps at East Park will be required.

A rapid filter plant has been adopted at East Park.

In considering the Schuylkill and Delaware rivers as sources of supply to be filtered for the city, we have decided upon the following main points:

a. To utilize and adopt the present plants as far as possible and to the best advantage.

b. To use the Schuylkill water for the districts of Belmont, Roxborough and Queen Lane, with such surplus as may remain of the limited 150,000,000 gallons supply per day, for East Park.

c. To abandon the reservoir at Fairmount, which is now in use only for about seven months in the year, and to connect the turbine pumps with Spring Garden station, so that they may be placed in service whenever the supply of water will allow, thereby relieving the steam plant of a corresponding amount of work.

d. To abandon the Corinthian reservoir.

e. To retain the Fairhill reservoir, which, although not now designated for use, will hereafter undoubtedly be found valuable as a centre of distribution for filtered water and can be so adapted by modification and covering.

f. To adopt slow filtration for Belmont, Roxborough and Queen Lane districts, and rapid filtration for such remaining portion of the Schuylkill water as is delivered at East Park.

g. To establish a slow-filter plant on the Delaware

river below Torresdale, from which all the water not supplied from the Schuylkill will be obtained.

h. To make use of the present reservoirs, whenever possible, for sedimentation and for the storage of filtered water.

j. To allow at least 24 hours for sedimentation, and to provide storage capacity for one-half day's supply of filtered water.

k. To cover all storage reservoirs for filtered water.

l. To cover all filters.

It is, of course, eminently desirable that the water supplies for filtration should be as free from impurities as possible, so as to reduce to a minimum the duty on the filters; and every effort should be made, by legislation and otherwise, to prevent the pollution of streams; yet such water as exists to-day, in the Schuylkill and Delaware rivers at the City of Philadelphia, can be purified by filtration and rendered wholesome and fit for all domestic purposes.

Within the city limits it is possible to locate the filter plants at places where the water supplied them will not be subject to direct sewage polution. A point can be selected on the Delaware river within the city limits, but above such direct contamination, and the present intakes on the Schuylkill are well situated in this respect. The locations and conditions of existing pumping stations and reservoirs are such that it is advisable to continue the use of the water in this river up to a quantity equal to its minimum flow, at least so long as the present plant can be made serviceable. For additional supply, and for future extensions, the Delaware is the proper source, and in time it is not impossible that the whole supply may come from that river.

In order to ascertain the suitability of certain sands, obtainable in the vicinity of Philadelphia, for use in

filter plants, we have had mechanical analyses made of a number of samples. The results, which are given in Appendix V, indicate that there will be no difficulty in obtaining suitable material for the purpose.

If the annual rates remain the same, the surplus earnings of the Bureau of Water would, to all appearances, be sufficient to pay for the continual extension of the plant as required by the growth of the city.

Owing to the improvements constantly being made in the operation of filtration plants, it is probable that our estimated cost of filtration will be found, in the future, to have been too high, rather than too low.

It will be noticed that the estimated cost of filtering on the Delaware is slightly less than on the Schulkill.

When the present reservoirs are converted into settling reservoirs for use prior to the filtration of the water, it will be necessary, in some instances, to re-adjust the water intakes and outlets, so as to accomplish the highest possible degree of sedimentation during the time that the water is passing through the reservoir.

It is advisable that filters and clear-water reservoirs be covered or roofed, to prevent the formation of ice on the surface and to protect the filtered water from pollution by the dust in the air which carries the seeds of lower life. There is abundant evidence of the deterioration of filtered water, or of spring water, kept in open reservoirs. In covered reservoirs, the water is also cooler in summer, than when exposed to sunlight. There is an erroneous idea that sunlight and air are advantageous to stored water. The contrary has been frequently demonstrated, and everyone appreciates the excellence of spring water, which issues, so to speak, from the bottom of a large natural filter, without having been exposed to either sunlight or air. There are both chemical and biological reasons for these facts.

The slow-filter plants contemplated in our recommendations are similar, in general arrangement, to those of London and of Hamburg, and to the recently completed filter plant at Albany, N. Y. The latter is the largest filtration plant in this country.

The following plates illustrate the plans for the several filter plants and show how it is proposed to utilize the present reservoirs for subsidence and for filtered-water reservoirs.

Plate IX. Locations of filter plants and mains recommended for immediate relief.

Plate X. Belmont filter plant.

Plate XI. Roxborough filter plant and Queen Lane filter plant.

Plate XII. East Park filter plant.

Plate XIII. Torresdale filter plant.

Plate XIV. Plan and sections of typical slow-filter.

Plate XV. Details of sand washers and regulating apparatus.

We have said that we consider it inadvisable during dry years to obtain a greater amount of water from the Schuylkill river than 150,000,000 gallons per day. A provision for supplying the city with 200,000,000 gallons daily, therefore, requires 50,000,000 gallons a day to be obtained from the Delaware river; and all future increase of supply is assumed to be taken from this river. We have selected the neighborhood of Torresdale as the site for the new pumping station on the river because the present site at Lardner's Point will, in our opinion, not be suitable in the future, on account of the several large sewers now delivering, or which will soon deliver, a large amount of sewage into the river in that neighborhood.

From data at hand and from our estimates of the growth of the city, we have made the distribution of the total daily quantity of water required as follows:

For a supply of 200,000,000 gallons per day:

Belmont station	27,000,000 gallons dai
Roxborough station	15,000,000 gallons dai
Queen Lane station	58,000,000 gallons dai
Spring Garden station	50,000,000 gallons dai
Torresdale station	50,000,000 gallons dai
Making a total of	200,000,000 gallons dai

It is proposed to add, at Belmont station, one new pum ing engine of 20,000,000 gallons daily capacity.

For a supply of 300,000,000 gallons per day:

Belmont station	37,000,000 gallons dai
Roxborough station	25,000,000 gallons dai
Queen Lane station	58,000,000 gallons dai
Spring Garden station	30,000,000 gallons dai
Torresdale station	150,000,000 gallons dai
Making a total of	300,000,000 gallons dai

It is proposed to erect, at East Park filter plant, tv 12,000,000-gallon pumping engines to pump from Ea Park reservoir into the Queen Lane district, in order supply the deficiency between the amount pumped rectly at Queen Lane station and the consumption Queen Lane district.

For a supply of 450,000,000 gallons per day:

Belmont station	55,000,000 gallons dai
Roxborough station	37,000,000 gallons dai
Queen Lane station	58,000,000 gallons dai
Spring Garden station	
Torresdale station	300,000,000 gallons dai
Making a total of	450,000,000 gallons dai

If the future water supply is obtained from the rive and filtered, it will be necessary to make a few chang in the pumping machinery and reservoirs.

At Fairmount, the reservoir is too low for a prop service, being only 94 feet above tide. Also it is ine

pedient to filter the water at this station, and for these reasons we have recommended the abandonment of the Fairmount reservoir.

The Spring Garden reservoir would be of no use in the new apportionment and might be abandoned as a reservoir, unless retained for the use of Girard College.

At Belmont, the present reservoir, with slight alterations, could be used as a settling reservoir. A new 20,000,000-gallon pumping engine should be added to the station at the Schuylkill river, to be used as a reserve.

By limiting to 150,000,000 gallons per day the amount of water to be obtained from the Schuylkill river, it became necessary to re-apportion the amounts to be supplied to each station, as it was evident that at the present time more than the above amount is actually pumped from the Schuylkill river. We found it to be more economical, therefore, to limit the amount of water to be supplied to the Queen Lane district from the Schuylkill river, and to furnish the deficiency hereafter from the Delaware river.

The quantity thus supplied to the Queen Lane district from the Schuylkill river is to be secured from the East Park reservoir by a new pumping station at the East Park filter plant, with proper engine capacity to pump from this resevoir into the Queen Lane district.

A portion of the Queen Lane reservoir is to be converted into a clear-water reservoir discharging into the City mains.

The East Park reservoir, being very large, will not only serve as a storage reservoir for Schuylkill water, but also for the excess delivered in the future from the Delaware river. A part of this reservoir is to be converted into a clear-water reservoir delivering into the city mains.

The new Roxborough reservoir is to be kept in use, but a part of it is to be converted into a clear-water reservoir.

The Mount Airy reservoir will be used, and the old Roxborough reservoir may be temporarily put out of use.

The Frankford reservoir will be converted into a clear-water reservoir.

The Lehigh reservoir can be temporarily placed out of use, and eventually converted into a clear-water reservoir if found necessary.

In assigning the quantity of water to be supplied to the several districts, and the capacity required of the filtration plant for each, consideration has been given to their probable relative growth and increase in population, as some districts, particularly those of suburban character, will undoubtedly show a much greater annual increase than others.

The lower levels in the Roxborough district, now supplied from the new reservoir, with its great elevation of 414 feet, could be more economically supplied from the Queen Lane reservoir if proper mains were laid for the purpose. Indeed, a portion of the lower Roxborough district is already supplied by a main which taps the Queen Lane pumping main near the station.

In connection with the gravity supply from the Delaware River, a new distributing reservoir near Olneyville, at the point of discharge of the conduit, is proposed. The cost of this reservoir is estimated at $1,000,000.

A new reservoir at Belmont, adjoining the present reservoir, for the sedimentation of raw water, may be required when the present consumption has been materially increased. It probably need not be more than half as large as the reservoir recently proposed.

As the demands of the Belmont, Roxborough and Queen Lane districts increase, the surplus of the Schuylkill water delivered at East Park during minimum flow will gradually diminish; and this deficiency, together with what will be required for increased consumption all

over the city, is to be supplied from the Delaware through the Torresdale filter plant. When the Schuylkill is flowing above its minimum, which will be during most of the year, the supply will be ample to keep the East Park plant in full service as well as the others.

To abandon completely at this time the present Schuylkill plants would mean the abandonment of much valuable pumping machinery and other works, and also a loss of time in making the change. This change would require not only that a large additional plant be in operation on the Delaware before the Schuylkill plant could be removed, but also the laying of large and costly mains to bring the water to the city.

Upon the completion of the proposed Torresdale pumping station, the Frankford station would be abandoned.

The standpipes at Belmont, Roxborough and Chestnut Hill will be kept in use, but will be supplied with filtered water instead of with raw water.

RÉSUMÉ AND CONCLUSIONS.

We now desire to re-state briefly what has been stated at length in the preceding pages, and to present the conclusions derived from our examinations.

The deplorable condition of the City's water supply, which it is sought to remedy, is due to the pollution of its sources, to the lack of effective pumping machinery, and to the insufficient capacity of the distributing system.

The question of first importance is the source of supply, and to this nearly all of our thought and time has been devoted.

Most of the water is now obtained from the Schuylkill river, within the city limits. Five pumping stations take

from it about 200,000,000 gallons daily. One pumping station is located on the tidal estuary of the Delaware river at Lardner's Point, and supplies about 15,000,000 gallons daily.

The Schuylkill water is being polluted at many points from its source down to the city line. Beginning with the mine waters, the coal dust and some sewage from the upper parts of the water-shed, the pollution is increased below by the sewage of cities and villages situated along the river and its chief tributaries, by the manufacturing refuse and by the surface water from agricultural districts, all of which render the water sometimes turbid, unpalatable, impure and dangerous to health.

The Delaware water at Lardner's Point is less turbid after rains than the Schuylkill water; it is also softer and less polluted. Its flow is many times larger. While this water is, therefore, now somewhat better than the Schuylkill water, the growth of the city, the newly-built or projected sewers above and below the intake, and the tidal oscillation of the water, tend to a continually increasing pollution also of the water taken from the Delaware river.

It, therefore, becomes imperative, either to select a new source of supply or to improve the present one, so that it will become thoroughly satisfactory to the citizens both as to quality and quantity. The first project requires the bringing of Blue Mountain water to the city; the second requires a thorough filtration of the Schuylkill and Delaware waters taken within the city limits. A decision as to which of these alternative projects is the better one must be based on the quality and quantity of water to be supplied and on the cost.

It was, therefore, necessary first to make certain preliminary assumptions, then to make designs for both projects, and to ascertain the cost of construction and

operation. The assumptions as to population, and as to quality and quantity of water are as follows:

The present population, to be supplied from the city's pipe system as soon as practicable, is taken at 1,300,000 persons. The population to be held in view in the design for new works is assumed at 3,000,000 persons.

It was considered that the waters collected from the affluents of the Delaware and Lehigh rivers in the Blue Mountains, and from the Upper Perkiomen creek, could be used in their natural condition. While these natural sources are the best obtainable at a reasonable cost, and while their average standard of purity is high, it must be remembered that a guarantee against an occasional and temporary pollution of the water by disease germs from man and animals, cannot be given for such large and exposed water-sheds. Nor can an occasional taste, due to vegetal matter, be entirely avoided.

The alternative source of supply is the water of the Schuylkill and Delaware rivers, within or near the city limits, artificially purified to the required standard. The purification is obtained by filtering the water through sand; no better and cheaper method is known.

The progress made in this country and in Europe in ascertaining the laws of the mechanical and biological process of filtration, and the practical success obtained in filtering water for many years in large cities of Europe, confirm and warrant the conclusion that this method of purification can furnish this City, from both rivers, with water that will be clear and palatable, and will conform to the best bacterial and chemical standards.

When the raw river water carries much suspended matter with it, this must be allowed to subside, as a preliminary to filtration, so as to lengthen as much as practicable the time between the filter cleanings. Settling reservoirs are therefore essential as preliminaries to the

filtration of the water of these two rivers. In order to secure the greatest practicable efficiency, the filter plant must not only be built with skill, and be provided with the best means for regulating the flow, and for cleaning the sand, but it must also be carefully operated by trained men, in accordance with the daily condition of the river water and of the filters.

The quantity of water required for city consumption depends on local conditions. In some cities much less water is used than in others. The quantity with which Philadelphia has generally been credited, is somewhat misleading, due to the absence of proper measuring appliances; as a matter of fact, it is less than appears on the records. There is also, in this city, an undoubted waste of water, the amount of which cannot now be accurately determined, and which confers no benefit whatever, either to persons or property, or for street or sewer cleaning. It, therefore, subjects the citizens at large to an entirely useless expenditure, which should be stopped at the earliest practicable moment.

We consider that, at present, a daily supply of 200,000,000 gallons, being 150 gallons per capita, is a very liberal allowance. We recommend that this quantity of pure water be immediately provided for. At the same rate, a population of 3,000,000 persons will require a daily supply of 450,000,000 gallons.

Comparative estimates of cost have been made for eventually supplying these quantities. In order to indicate the legitimate outcome of an extravagant use of water, we have made a further estimate of cost for supplying the city daily with 700,000,000 gallons of mountain waters.

The Blue Mountain water projects deliver water to the city reservoirs by gravity. In one, mountain water is obtained from the upper Perkiomen creek and from the

Lehigh river with its tributaries. In another, mountain water is taken from the Delaware tributaries near the Water Gap. Still another project was considered using the Delaware water at Portland below the Water Gap, but after filtration. Other projects were considered, but were found to possess no special advantages, and were also more expensive.

The filtered water project which has been specially considered, is confined to taking water from the Schuylkill and Delaware rivers within the city limits.

Two methods of filtration are in common use; one allows the water to percolate slowly through a bed of sand, while the other allows it to pass through much more rapidly, and, in order to give it the same degree of purity, requires the use of a coagulating substance to prevent objectionable organisms and suspended matter from passing through the filter. The first we have called a slow, and the second, a rapid filtration.

Inasmuch as it has been impossible, in the time at our disposal, to make the necessary experiments showing the precise effects of filtering both the Schuylkill and Delaware waters, either through slow or rapid filters, it is also impossible now to state which of the two systems would be the more economical. But we know, and can positively assert, from experience obtained elsewhere, that, for the plants which we have recommended, a slow filter system will not materially differ in annual expense from a rapid filter system. We likewise know that the slow filters, from long experience, and from their successful operation in many cities, can, without question, yield satisfactory results with the waters of the above-mentioned rivers. The rapid filters have only recently been sufficiently developed to command a high degree of confidence in their results under all circumstances.

We are of the opinion that for the present supply, slow filters should be adopted at every station in the city, ex-

cepting at the one near East Park reservoir. We believe that at the latter station a rapid filter plant would be more serviceable.

A comparison of the estimates of cost shows the following results:

The most economical project for a supply of mountain water is that taken from the upper Perkiomen and from the Lehigh water sheds. For immediate needs, its cost of construction is $33, 410,000. Its annual cost, for operation, interest on investment, and all expenses, to deliver the water into the City reservoirs, is $1,205,000.

For a daily supply of 450,000,000 gallons, the total first cost would be $66,740,000, and the annual cost $2,480,000.

The most economical project for a supply of filtered water is that by which the waters of the Schuylkill and Delaware rivers are filtered within the City limits. Its cost of construction, for present requirements, would be $10,974,000. Its annual cost, for operation, interest and all other expenses, to deliver the water into the City reservoirs, is $1,227,000.

For a daily supply of 450,000,000 gallons, the total cost of the filter plant, including special mains from Torresdale to the centre of the city, would be $34,155,000, and the annual cost $2,972,000.

The estimates of cost have shown three important results:

1. The original cost of any of the mountain water supplies is very great for the large quantities of water which the city requires.

2. A filtered water supply can be obtained at a first cost which is within the present borrowing capacity of the city, and the plant can be operated at a cost which will not exceed the probable annual net earnings of the water works.

3. The total annual cost of delivering the water into the City reservoirs, by either method, is about the same, and the annual earnings will cover the operation and extension.

In conclusion we recommend :

1. The adoption of that project by which the waters of the Schuylkill and Delaware rivers, taken within the City limits, are purified by filtration.

2. The immediate improvement of the existing plant, in accordance with the detailed recommendations of our report.

The necessity for the second of these recommendations is manifest. Our reasons for the first are as follows:

The entire works can be built for a sum which the City can secure at this time through a loan.

A supply of pure water for the entire City can be obtained within a comparatively short time, and the City can thus at an early day be protected against a continuance of those diseases which are known to be caused by the present polluted water supply.

A filtered water supply, under skillful management, offers a greater security against the effects of accidental pollution of the water, than is possible when the supply is taken from open, unprotected water courses. Filtration can, without difficulty, be made to render the water thoroughly wholesome.

The two large rivers at Philadelphia, or even the Delaware river alone, can furnish, at all times, a quantity of water sufficient for a very large city.

The foregoing is respectfully presented.

RUDOLPH HERING.
JOSEPH M. WILSON.
SAMUEL M. GRAY.
Commissioners.

APPENDICES

CONTENTS.

APPENDIX I.

Furnished by Bureau of Health.

A

Total Residue Precipitated in Parts per Million.

Semi-Weekly Observations of Schuylkill River Water.

Date.	Residue.	Date.	Residue.	Date.	Residue.	Date.	Residue.
1898. Jan. 3	10.	April 4	12.	July 5	7.	Oct. 3	5.
6	3.	7	5.	7	14.	6	8.
10	3.	11	8.	11	17.	10	12.
13	4.	14	8.	14	13.	13	12.
17	47.	18	9.	18	22.	17	11.
20	7.	21	14.	21	9.	20	14.
24	183.	25	17.	25	13.	24	15.
27	53.	28	22.	28	27.	27	19.
31	10.	May 2	13.	Aug. 1	16.	31	20.
Feb. 3	5.	5	13.	4	21.	Nov. 3	14.
7	2.	9	149.	8	107.	7	10.
10	11.	12	37.	11	152.	10	8.
14	16.	16	88.	15	41.	14	20.
17	19.	19	23.	18	29.	17	9.
21	545.	23	51.	22	80.	21	40.
24	35.	26	28.	25	25.	24	14.
28	2.	30	18.	29	17.	28	15.
March 3	6.	June 2	23.	Sept. 1	10.	Dec. 1	5.
7	2.	6	12.	6	11.	5	416.
10	6.	9	9.	8	20.	8	71.
14	11.	13	10.	12	16.	12	6.
17	7.	16	20.	15	7.	15	14.
21	23.	20	17.	19	7.	19	7.
24	18.	23	16.	22	11.	22	52.
28	12.	27	13.	26	7.	27	32.
31	50.	30	33.	29	7.	29	18.

Total Residue Precipitated in Parts per Million in Schuylkill River Water—Continued.

Date.	Residue.	Date.	Residue.	Date.	Residue.	Date.	Residue.
1899 Jan. 5......	9.	Mar. 2......	77.	May. 4......	15.	June. 26.....	10.
9......	17.	6......	325.	8......	7.	29......	17.
12......	6.	9......	27.	11......	15.	July. 3......	104.
16......	5.	13......	1026.	15......	15.	24......	15.
19......	48.	23......	130.	18......	20.	27......	15.
23......	4.	27......	23.	22......	21.	31......	17.
26......	403.	30......	116.	25......	18.	Aug. 3......	31.
30......	13.	April. 4.....	21.	29......	8.	7......	48.
Feb. 2......	5.	6......	10.	June. 1......	17.	10......	12.
6......	26.	10.....	92.	5......	9.	14......	35.
9......	8.	20......	21.	8......	8.	17.	71.
15......	6.	24......	21.	12......	15.	21......	12.
20......	38.	27......	36.	15......	7.	24......	10.
23......	224.			19......	9.	28......	48.
27......	642.	May. 1......	10.	22......	22.	31......	41.

B

Total Residue Precipitated in Parts per Million. Daily Observations.

Date.	Delaware Water at Lardner's Point.			Schuylkill Water at Spring Garden.		
	By acid.	In 24 hrs.	In 48 hrs.	By acid.	In 24 hrs.	In 48 hrs.
1899.						
July 19	16.	6.5	9.	13.5	12.6	6.5
20	9.1	7.5	6.	9.9	3.7	6.5
21	7.5	8.6	5.	10.6	5.	6.5
22	13.5	14.6	10.	17.6	12.5	8.5
23	....	....	....	....	....	....
24	10.	9.5	9.6	14.5	23.6	7.
25	15.	12.5	19.6	13.5	16.6	10.5
26	16.	10.5	9.6	18.5	19.6	19.5
27	10.	17.5	9.1	16.5	22.6	7.5
28	14.4	7.5	9.1	10.5	14.6	7.5
29	15.	17.	18.6	4.5	6.6	12.
30	....	....	....	....	....	....
31	26.	29.5	29.5	16.5	19.6	21.5
August 1	24.5	22.5	22.5	18.5	16.5	17.5
2	22.	19.5	21.	28.5	26.	29.
3	41.7	46.	50.	39.5	31.	38.
4	24.	21.	26.	49.	59.5	63.
5	15.	14.5	16.	23.	30.	34.
7	15.	15.	16.	33.	36.	39.
8	13.	15.	15.	27.	26.	32.
9	15.	14.	18.	28.	22.	27.
10	16.	16.	15.	19.	13.	17.
11	22.	24.	27.	131.	130.	144.
12	24.	21.	22.	362.	315.	334.
13	....	....	....	103.	72.	74.
14	20.	16.	18.	65.	40.	42.
15	29.	24.	27.	67.	48.	48.
16	29.	22.	26.	104.	57.	71.
17	31.	24.	28.	78.	47.	50.

Total Residue Precipitated in Parts per Million. Daily Observations—Continued.

Date.	Delaware Water at Lardner's Point. By Acid.	Delaware Water at Lardner's Point. In 24 hrs.	Delaware Water at Lardner's Point. In 48 hrs.	Schuylkill Water at Spring Garder. By Acid.	Schuylkill Water at Spring Garder. In 24 hrs.	Schuylkill Water at Spring Garder. In 48 hrs.
1899.						
August 18	31.	19.	24.	47.	25.	27.
19	20.	17.	18.	21.	15.	17.
20	15.	14.	17.	23.	14.	18.
21	19.	18.	20.	16.	14.	15.
22	31.	21.	23.	19.	19.	19.
23	19.	15.	15.	23.	13.	18.
24	14.	16.	13.	19.	16.	13.
25	13.	8.	9.	14.	8.	9.
26	14.	12.	14.	11.	11.	15.
27	9.	11.	11.	25.	30.	30.
28	19.	11.	11.	55.	47.	47.
29	17.	16.	16.	44.	38.	43.
30	13.	11.	12.	69.	48.	43.
31	18.	12.	14.	53.	40.	38.
September 1	12.	14.	12.	25.	18.	19.
2	14.	13.	13.	26.	12.	14.
3	12.	10.	14.	16.	16.	18.
4	14.	11.	14.	30.	22.	34.
5	13.	11.	12.	32.	23.	28.
6	15.	10.	11.	22.	21.	19.
7	17.	12.	17.	30.	26.	24.
8	20.	17.	21.	25.	15.	12.
9	15.	13.	15.	28.	16.	16.
10	19.	16.	16.	28.	19.	18.
11	14.	11.	12.	22.	23.	21.
12	17.	11.	14.	23.	21.	22.
13	14.	12.	13.	25.	21.	21.
14	18.	14.	19.	23.	21.	24.
15	20.	15.	21.	22.	18.	19.
16	14.	12.	13.	17.	16.	16.

APPENDIX II.

Reservoir and Standpipe Data.

	Surface High Water above City Datum. Feet.	Depth of Water. Feet.	Capacity in Gallons.	Number of Compartments.	Future Use if Water is Filtered.
......	94	12	26,350,000	4	To be abandoned.
......	120	27	37,341,000	1	To be temporarily out of use.
......	120	17	12,950,000	1	To be temporarily out of use.
......	133	25	688,618,000	3	To be used and partly converted into clear water basins.
......	212	25	39,758,000	2	To be used with slight alterations.
......	238	30	383,100,000	2	To be used and partly converted into clear water basins.
......	363	15	4,546,000	2	To be used.
......	366	20	12,838,000	1	To be temporarily out of use.
......	414	25	147,032,000	2	To be used and partly converted into clear water basins.
......	167	23	36,046,000	1	To be converted into clear water basios.
......	114	{ 19 13 }	28,910,000	2	To be temporarily out of use.
......	364	148	106,000	....	To be used.
......	491	148	106,000	....	To be used.
......	481	12	52,000	....	To be used.

APPENDIX III.

ESTIMATES OF COST.

Construction, Operation, and Maintenance.

APPENDIX III.

BASIS OF ESTIMATES.

Cost of Pumping,

Per million gallons raised one foot high, including coal, labor, oil, waste and supplies, and ordinary repairs; but excluding interest and depreciation:

High-Lift Pumps.

For a daily supply of

200,000,000 gallons,	300,000,000 gallons,	450,000,000 gallons,
3.5 cents.	3.25 cents.	3.0 cents.

Low-Lift Pumps.

For a daily supply of

200,000,000 gallons,	300,000,000 gallons,	450,000,000 gallons,
5.25 cents.	4.875 cents.	4.5 cents.

For stations away from railroad sidings add to all above prices 0.5 cent.

Cost of Filtration,

Per million gallons of filtered water, including labor, cost of wash and waste water, lost sand, sanitary analyses of water, chemicals, superintendence, watchmen, ordinary repairs, and all incidental expenses; but excluding interest, depreciation and cost of pumping water to filters:

	Schuylkill River.	Delaware River, At Portland.	Delaware River, At Torresdale.
Slow filters	$3.60	....	$3.00
Rapid filters	4.80	$3.20	4.00

Interest and Depreciation.

Interest on cost of works is assumed at 3%.

Depreciation of works is assumed as follows:

Structures, Apparatus, etc.	Life, in Years.	Annuity on One Dollar.
Masonry Conduits	Permanent.	
Covered Masonry Filter Beds	Permanent.	
Covered Reservoirs	Permanent.	
Permanent Buildings	100	.00165
Cast-iron Pipe	80	.00311
Railroad Sidetracks	80	.00311
Steel Pipe	35	.01654
Air Valves, Blow-offs and Gates on Pipe Lines	35	.01654
Engines and Pumps	30	.02102
Boilers	20	.03722
Rapid Filters and Appurtenances	20	.03722
Electric Light Plants	20	.03722
Tramways and Equipment	20	.03722
Iron Fences	20	.03722
Telephone Lines	10	.08724
Sand-washer Apparatus	10	.08724
Regulating Apparatus for Slow Filters	10	.08724

Unit Prices.

Aqueducts, Tunnels, Steel-Pipe Lines and Dams.

Clearing and grubbing, per acre	$100 00
Earth excavation, per cubic yard	30
Borrowed earth, per cubic yard, per 1,000-foot haul	20
Overhaul, 5 cents per 1,000 feet; limit, 60 cents.	
Rock excavation, granite, etc., in tunnel, per cubic yard	5 00
Rock excavation, shale and soft rock in tunnel, per cubic yard.	4 00
Rock excavation, open cut, per cubic yard	1 20
Shaft excavation, per linear foot, Perkiomen	40 00
Shaft excavation, per linear foot, Lehigh and Delaware	100 00
Dry rock filling over arch in tunnel, per cubic yard	2 50

Unit prices, continued.

Rubble masonry filling in tunnel, per cubic yard	$5 00
Brick masonry in tunnel, per cubic yard	12 00
Brick masonry in trench, per cubic yard	12 00
Arch culvert masonry, per cubic yard	15 00
Rectangular culvert masonry, per cubic yard	10 00
Foundation masonry, per cubic yard	6 00
Retaining walls and cradling, per cubic yard	5 00
Rubble stone masonry in trench, per cubic yard	5 50
Paving, per cubic yard	2 00
Portland cement concrete in tunnel...... 1 : 3 : 6	7 00
Portland cement concrete in trench...... 1 : 3 6	6 00
Portland cement concrete.................. 1 : 2½: 4½	7 50
Portland plastering on arch, per linear foot, 12-foot aqueduct	25
Portland cement wash, invert and sides, per linear foot of aqueduct	08
Riveted-steel pipes, coated and erected, per pound	06
Manholes, each	15 00
Blow-offs for 72-inch and 80-inch pipes, each	500 00
Blow-offs for 60-inch pipes, each	300 00
Air valves for 72-inch and 80-inch pipes, each	150 00
Air valves for 60-inch pipes, each	100 00
Gate-houses, including gates etc.	
With 4 lines of 80-inch pipe, each	$40,000 00
With 3 lines of 80-inch pipe, each	35,000 00
With 3 lines of 72-inch pipe, each	30,000 00
With 2 lines of 72-inch pipe, each	25,000 00
With 2 lines of 60-inch pipe, each	25,000 00
Railroad crossings, each, extra	2,000 00
Culverts over brooks, each, extra	10,000 00
Telegraph and telephone lines, per mile	600 00
Stone wall fence (two sides), per linear foot	40
Iron fence (two sides), per linear foot	2 00
Dressing and seeding banks, per square yard	08

MOUNTAIN WATER SUPPLY.

Cost of Construction.

Summary.

A.—For a daily supply of 200,000,000 gallons from the Upper Perkiomen creek and Lehigh river tributaries.

Perkiomen high-level aqueduct, 12-foot diameter	$9,490,000	
Lehigh aqueduct, 8-foot diameter	6,550,000	
Storage, Perkiomen	8,330,000	
Storage, Lehigh	7,720,000	$32,090,000
Distribution to Belmont reservoir	$245,000	
Distribution to Roxborough reservoir, including pumping station	370,000	
Distribution to East Park reservoir	235,000	
Distribution to Wentz Farm reservoir	470,000	$1,320,000
Total		$33,410,000

B.—For a daily supply of 200,000,000 gallons, from tributaries of Delaware river near the Water Gap.

Delaware aqueduct, 14-foot diameter	$31,690,000	
Storage, Delaware	14,850,000	$46,540,000
200,000,000-gallon reservoir, near Twelfth street and Olney avenue	$1,000,000	$1,000,000
Total		$47,540,000

C.—For a daily supply of 450,000,000 gallons from the UpperPerkiomen creek and Lehigh river, with tributaries.

Perkiomen high-level aqueduct, 12-foot diameter	$9,490,000	
Perkiomen low-level aqueduct, 12-foot diameter	9,050,000	
Lehigh aqueduct	18,700,000	
Storage, Lehigh	19,020,000	
Storage, Perkiomen	8,330,000	
		$64,590,000

Distribution to Belmont Reservoir from Queen Lane	$245,000	
Distribution to Belmont Reservoir from East Park.	155,000	
Distribution to Roxborough Reservoir, including pumping station	525,000	
Distribution to Wentz Farm Reservoir	990,000	
Distribution to East Park	235,000	
		$2,150,000
Total		$66,740,000

D.—For a daily supply of 450,000,000 gallons from the Delaware river tributaries, near the Water Gap, from the Upper Perkiomen creek, and from the Lehigh river tributaries.

Delaware aqueduct, 14-foot diameter	$31,690,000	
Storage, Delaware	14,850,000	
Perkiomen high-level aqueduct	9,490,000	
Lehigh aqueduct, 8-foot diameter	6,550,000	
Storage, Perkiomen	8,330,000	
Storage, Lehigh	7,720,000	
		$78,630,000
Distribution to Belmont reservoir	$475,000	
Distribution to Roxborough reservoir, including pumping station	525,000	
Distribution to East Park reservoir from Olney avenue	1,500,000	
Distribution to Wentz Farm reservoir from Queen Lane	470,000	
Distribution to Wentz Farm reservoir from Olney avenue	350,000	
Distribution to East Park reservoir from Queen Lane	235,000	
200,000,000-gallon reservoir near Twelfth street and Olney avenue	1,000,000	
		4,555,000
Total		$83,185,000

Annual Cost of Operation and Maintenance.

Summary.

A.—For a daily supply of 200,000,000 gallons from the Upper Perkiomen creek and Lehigh river tributaries.

Interest on $33,410,000	$1,002,300	
Depreciation of works	91,820	
Sanitary inspection	8,040	
Ordinary repairs	23,700	
Keepers' wages and pumping	68,490	
Sanitary analyses of water	11,000	
Total		$1,205,350
Say		$1,205,000
Cost per 1,000 gallons for the water delivered into the city reservoirs		1.65 cents.

C.—For a daily supply of 450,000,000 gallons from the Upper Perkiomen creek and Lehigh river, with tributaries.

Interest on $66,740,000	$2,002,200	
Depreciation of works	218,450	
Sanitary inspection	15,640	
Ordinary repairs	50,860	
Keepers' wages and pumping	166,650	
Sanitary analyses of water	25,000	
Total		$2,478,800
Say		2,480,000
Cost per 1,000 gallons delivered into the city reservoirs		1 51 cents.

D.—For a daily supply of 450,000,000 gallons from the Delaware river tributaries near the Water Gap, from the Upper Perkiomen creek, and from the Lehigh river tributaries.

Interest on $83,185,000	$2,495,550	
Depreciation of works	198,640	
Sanitary inspection	16,620	
Ordinary repairs	49,150	
Keepers' wages and pumping	140,770	
Sanitary analyses of water	25,000	
Total		$2,925,730
Say		2,925,000
Cost per 1,000 gallons delivered into the city reservoirs		1.78 cents.

SLOW FILTER SUPPLY.

Cost of Construction.

Summary.

F.—For a daily supply of 200,000,000 gallons: 150,000,000 gallons from the Schuylkill and 50,000,000 gallons from the Delaware river, near the city.

Belmont filter plant, complete	for 27 millions daily	$1,802,786 00
Roxborough filter plant, complete	for 15 millions daily	729,099 31
Queen Lane filter plant, complete	for 58 millions daily	2,416,566 30
East Park filter plant, complete	for 50 millions daily	1,288,740 89
Torresdale filter plant, complete	for 50 millions daily	3,216,398 55
Totals	200 millions daily	$9,453,591 05
Mains to connect Torresdale filter plant with East Park distribution system		$1,520,000 00
		$10,973,591 05

G.—For a daily supply of 450,000,000 gallons: 150,000,000 gallons from the Schuylkill and 300,000,000 gallons from the Delaware river, near the city.

Belmont filter plant, complete	for 55 millions daily	$3,751,386 00
Roxborough filter plant, complete	for 37 millions daily	1,782,457 79
Queen Lane filter plant, complete	for 58 millions daily	2,416,566 30
East Park filter plant, complete		1,594,640 89
Torresdale filter plant, complete	for 300 millions daily	13,629,628 53
Totals	450 millions daily	$23,174,679 51
Mains to connect Torresdale plant with East Park distribution system		10,980,000 00
		$34,154,679 51

Annual Cost of Operation and Maintenance.

Summary.

F.—For a daily supply of 200,000,000 gallons from the Delaware and Schuylkill rivers, near the city.

Interest on $10,973,591.05	$329,207 74	
Depreciation of plant	57,916 25	
Cost of pumping into reservoirs	566,499 36	
Cost of filtering water	273,750 00	
Total		$1,227,373 35
Cost per 1,000 gallons for the filtered water delivered into the city reservoirs		1.68 cents.

G.—For a daily supply of 450,000,000 gallons from the Delaware and Schuylkill rivers near the city.

Interest on $34,154,679.51	$1,024,640 39	
Depreciation of plant	205,539 65	
Cost of pumping into reservoirs	1,216,021 22	
Cost of filtering water	525,600 00	
Total		$2,971,801 26
Cost per 1,000 gallons for the filtered water delivered into the city reservoirs		1.81 cents.

RAPID FILTER SUPPLY.

Cost of Construction.

Summary.

H.—For a daily supply of 450,000,000 gallons from the Delaware river at Portland (two 12-foot aqueducts to Philadelphia).

Cost complete, including aqueducts, filter plants, all accessory works and distribution pipes to city reservoirs............ $67,862,747

J.—For a daily supply of 450,000,000 gallons from the Delaware river at Torresdale.

Cost complete, including filter plant, pipe lines and distribution pipes to city reservoirs.:.................................... $21,918,376

K.—For a daily supply of 450,000,000 gallons: 260,-000,000 gallons of mountain water from storage in the Delaware watershed above the Water Gap, and 190,000,000 gallons from the Delaware river filtered at Portland with rapid filters (two 12-foot aqueducts to Philadelphia.)

Cost, including storage reservoirs, aqueducts, rapid-filter plant, all accessories, and distribution pipes to city reservoirs....... $78,645,052

Annual Cost of Operation and Maintenance.

Summary.

H.—For a daily supply of 450,000,000 gallons from the Delaware river at Portland:

Interest on $67,862,747	$2,035,882 41
Depreciation of plant	222,558 80
Maintenance of aqueducts, storage reservoirs, etc.	46,400 00
Cost of pumping into city reservoirs	408,938 00
Cost of filtering water	525,600 00
Total	$3,239,379 21
Cost per 1,000 gallons for the filtered water delivered into the city reservoirs	1.97 cents.

J.—For a daily supply of 450,000,000 million gallons from the Delaware river at Torresdale.

Interest on $21,918,376	$657,551 00
Depreciation of plant	311,670 00
Cost of pumping into reservoirs	1,411,796 00
Cost of filtering water	727,589 00
Total	$3,108,606 00
Cost per 1,000 gallons for the filtered water delivered into the city reservoirs	1.89 cents.

K.—For a daily supply of 450,000,000 gallons: 260,000,000 gallons of mountain water from storage in the Delaware watershed above the Water Gap, and 190,000,000 gallons from the Delaware river filtered at Portland with rapid filters.

Interest on $78,645,052	$2,359,351 56
Depreciation of plant	202,465 90
Maintenance of aqueducts and storage reservoirs	63,540 00
Cost of pumping into city reservoirs	323,528 00
Cost of filtering water	221,920 00
Total	$3,170,805 46
Cost per 1,000 gallons for the water delivered into the city reservoirs	1.93 cents.

SLOW FILTER SUPPLY.

Cost of Construction.

Belmont Filter Plant.

Capacity, 27,000,000 gallons daily.

Land	$322,500 00
Excavation	31,200 00
Piping, including specials	211,022 00
Piping for sand washers	800 00
Drains	1,530 00
Sand washers	2,400 00
13 Filter beds, complete	490,568 00
Pumping machinery	225,000 00
Filtered-water reservoir, (capacity, 15,000,000 gallons)	220,000 00
Electric light plant	10,000 00
Double-track tramway, cars and equipment	5,120 00
Residence for superintendent	5,000 00
Proportional part of cost of bacteriological laboratory	3,500 00
Office and store-room	5,000 00
Shelter, lunch-room and conveniences	10,000 00
Fencing	15,000 00
Cleaning up, etc.	9,000 00
	$1,567,640 00
15 per cent	235,146 00
Total	$1,802,786 00

Belmont Filter Plant.

Capacity, 55,000,000 gallons daily.

Land	$322,500 00
Excavation	62,500 00
Piping, including specials	387,205 00
Piping for sand washers	1,200 00
Drain pipe	3,910 00
Sand washers	4,200 00
26 Filter beds, complete	974,910 00
Pumping plant at sedimentation basins	424,000 00
Filtered-water reservoir, (capacity, 26,000,000 gallons)	400,000 00
Additional sedimentation basin at Belmont reservoir	100,000 00
Electric light plant	15,000 00
Additional pumping plant at river station	484,300 00
Double-track tramway, cars and equipment	11,250 00
Residence for superintendent	5,000 00
Proportional part of cost of bacteriological laboratory	6,100 00
Office and store-room	5,000 00
Shelter, lunch-room and conveniences	20,000 00
Fencing	15,000 00
Cleaning up, etc	20,000 00
	$3,262,075 00
15 per cent	489,311 00
Total	$3,751,386 00

Roxborough Filter Plant.

Capacity, 15,000,000 gallons daily.

Land	$35,000 00
Excavation	19,250 40
Piping, including specials	64,242 00
Water mains for sand washers	1,000 00
Drain pipe	1,130 00
Sand washers	1,200 00
8 Filter beds, complete	303,697 00
Pumping plant	58,400 00
Roofing filtered-water reservoir	106,480 00
Double-track tramway, cars and equipment	2,800 00
Residence for superintendent	5,000 00
Proportional part of cost of bacteriological laboratory	2,000 00
Office and store-room	5,000 00
Shelter, lunch-room and conveniences	10,000 00
Fencing	10,800 00
Cleaning up, etc	8,000 00
	$633,999 40
15 per cent	95,099 91
Total	$729,099 31

Roxborough Filter Plant.

Capacity, 37,000,000 gallons daily.

Land		$35,000 00
Excavation		38,526 80
Piping, including specials		113,540 50
Water mains for sand washers		1,500 00
Drain pipe		2,510 00
Sand washers		3,000 00
18 Filter beds, complete		680,536 00
Pumping Plant:		
At river station	$174,800 00	
At filters	87,200 00	
		262,000 00
New force main from river station to reservoir		142,500 00
Roofing filtered-water reservoir		212,960 00
Double-track tramway, cars and equipment		6,000 00
Residence for superintendent		5,000 00
Proportional part of cost of bacteriological laboratory		4,100 00
Office and store-room		5,000 00
Shelter, lunch-room and conveniences		15,000 00
Fencing		10,800 00
Cleaning up, etc		12,000 00
		$1,549,973 30
15 per cent		232,496 00
Total		$1,782,469 30

Queen Lane Filter Plant.

Capacity, 58,000,000 gallons daily.

Land	$310,000 00
Excavation	66,382 50
Piping, including specials	158,331 50
Piping for sand washers	3,000 00
Vitrified drain pipe	7,390 00
Sand washers	4,200 00
27 Filter beds, complete	1,009,949 00
Pumping plant at sedimentation reservoirs	100,000 00
Roofing filtered-water reservoir (capacity 40,000,000 gallons)	349,169 00
Electric light plant	15,000 00
Double-track tramway, cars and equipment	11,840 00
Residence for superintendent	5,000 00
Office and store-room	8,000 00
Shelter, lunch-room and conveniences	20,000 00
Fencing	15,600 00
Proportional part of cost of bacteriological laboratory	7,500 00
Cleaning up, etc	10,000 00
	$2,101,362 00
15 per cent	315,204 30
Total	$2,416,566 30

East Park Filter Plant.

Capacity, 50,000,000 gallons daily.

Rapid-filter plant, complete	$347,112 00
Building, including stack	215,000 00
Piping and specials, outside of building	51,850 00
Pumping plant for rapid filters	55,500 00
Roofing filtered-water reservoir	421,182 25
Changing roadways, sodding, etc	25,000 00
Proportional part of cost of bacteriological laboratory	5,000 00
	$1,120,644 25
15 per cent	168,096 64
Total	$1,288,740 89

East Park Filter Plant.

No water to be filtered at this station when total city consumption is 450,000,000 gallons daily.

Cost of plant as above	$1,120,644 25
New pumps to supply deficiency of 32,000,000 gallons daily in Queen Lane district	266,000 00
	$1,386,644 25
15 per cent	207,996 64
Total	$1,594,640 89

Torresdale Filter Plant.

Capacity, 50,000,000 gallons daily.

Land	$284,800 00
Excavation	55,382 80
Piping, including specials	77,014 50
Piping for sand washers	2,000 00
Drain pipe	6,060 00
Sand washers	3,600 00
24 Filter beds, complete	904,236 00
Pumping plant	848,655 00
Filtered-water reservoir at Torresdale	60,000 00
Filtered-water reservoir at Wentz farm	175,000 00
Sedimentation reservoirs	307,420 00
Double-track tramway, equipment and cars	9,700 00
Residence for superintendent	5,000 00
Proportional part of cost of bacteriological laboratory	7,000 00
Office and store-room	8,000 00
Shelter, lunch-room and conveniences	20,000 00
Fencing	5,000 00
Sidetrack from Pennsylvania Railroad	8,000 00
Cleaning up, etc	10,000 00
	$2,796,868 30
15 per cent	419,530 25
Total	$3,216,398 55

Torresdale Filter Plant.

Capacity, 300,000,000 gallons daily.

Land	$284,800	00
Excavation	314,555	80
Piping, including specials	504,354	50
Raw-water conduit	224,964	00
Filtered-water conduit, including manholes, gate houses, etc	77,975	60
Water mains for sand washers	13,000	00
Drain pipe	41,648	00
Brick drains	46,226	00
Sand washers	21,600	00
138 Filter beds, complete	5,159,087	00
Pumping plant	2,325,620	00
Filtered-water reservoir at Torresdale	322,500	00
Filtered-water reservoir at Wentz farm	528,000	00
Sedimentation reservoirs	1,712,420	00
Double-track tramway, cars and equipment	54,800	00
Residence for superintendent	5,000	00
Proportional part of cost of bacteriological laboratory	32,300	00
Office and store-room	30,000	00
Shelter, lunch-room, and conveniences	100,000	00
Fencing	15,000	00
Sidetrack from Pennsylvania Railroad	8,000	00
Cleaning up, etc	30,000	00
	$11,851,850	90
15 per cent	1,777,777	63
Total	$13,629,628	53

MOUNTAIN WATER SUPPLY.

Cost of Construction.

Storage.

Reservoirs, Intake-dams, Connecting Pipes and Accessory Works.

Perkiomen watershed	$8,330,000 00
Lehigh watershed:	
Above Big creek	10,650,000 00
Big and Aquanchicola creeks	8,370,000 00
Delaware watershed	14,850,000 00

20 per cent. of the area of each reservoir is assumed to be stripped 12 inches deep.

Perkiomen High-Level Aqueduct.

Green Lane to Queen Lane Reservoir.

Diameter, 12 feet. Capacity, 225,000,000 gallons daily.

	Miles.	Total cost.	Cost per foot.	Description.
Aqueduct	14.00	$3,105,000	$42 20	Slope, .000167.
Tunnel.	6.30	2,170,000	65 30	Slope, .000167.
Steel Pipe	7.80	4,215,000	101 40	4 sections of four 80-inch pipes; slope, .0003. 5th section—three 72-inch pipes; slope, .001.
Totals	28.10	$9,490,000		

Average cost per foot, $64 00

Perkiomen Low-Level Aqueduct.

Green Lane to East Park Reservoir.

Diameter, 12 feet. Capacity, 225,000,000 gallons daily.

From	To	Miles.	Total cost.	Cost per foot	Description.
Green Lane...	Frederic	4.89	$1,225,000	$47 50	Two 72-inch pipes; slope, .0025.
Frederic........	Wissahickon	18.73	4,845,000	49 00	Aqueduct, 12-foot diameter; slope, .000167.
Frederic........	Wissahickon	4.83	1,600,000	62 80	Tunnel, 12-foot diameter; slope, .000167.
Frederic........	Wissahickon	1.08	755,000	132 50	Three steel pipes, 72-inch diameter; slope, .C01.
Wissahickon creek..........	East Park reservoir...	2.37	625,000	50 00	One 72-inch steel pipe, one 60-inch steel pipe; slope, .0035.
Totals.........	....	31.9	$9,050,000		

Average cost per foot, $53.80.

Lehigh Aqueduct.

White Haven to Aquanchicola Creek.

Section.	From	To	Miles.	Total cost.	Cost per foot.
I.	White Haven...	Muddy Run.....	8.24	$1,660,000	$38.20
II.	Muddy Run.....	Bear Creek......	6.91	2,050,000	56.10
III.	Bear Creek......	Big Creek.........	8.33	2,860,000	65.00
IV.	Big Creek...	Aquanchicola...	6.35	2,830,000	84.50
			29.83	$9,400,000	$59.70 (Average)

Aquanchicola Creek to Reservoir near Treichlersville.

Section V.	Miles.	Total cost.	Cost per foot.	Description.
Masonry Aqueduct........	20.2	$5,345,000	$50.10	12-foot aqueduct; slope, .00045.
Tunnel..........................	5.09	1,605,000	59.60	12-foot aqueduct; slope, .00045.
Steel Pipe.....................	3.39	2,230,000	124.50	Four 80-inch pipes; slope, .001.
Open Channel...............	0.95	120,000	24.00	20-foot channel.
	29.63	$9,300,000	$59.40 (Average)	

NOTES.

Section I: Capacity, 200,000,000 gallons daily. 14 300 feet, two 5-foot pipes; slope, .0055. 29 200 feet, one 10-foot aqueduct; slope, .0005.

Section II: Capacity, 250,000,000 gallons daily. 25 100 feet, two 5-foot pipes; slope, .008. 700 feet, two 6-foot pipes; slope, .004. 10 700 feet, 8-foot tunnel; slope, .002.

Section III: Capacity, 300,000,000 gallons daily. 34 800 feet, two 6-foot pipes; slope, .005. 9 200 feet, 10-foot tunnel; slope, .001.

Section IV: Capacity, 350,000,000 gallons daily. Three 80-inch pipes; slope, .002.

Section V: Capacity, 350,000,000 gallons daily.

Delaware Aqueduct.

Water Gap to Portland.

Diameter, 12 feet. Slope, .0003.
Capacity, 260,000,000 gallons daily.
Length, 5.86 miles.
Cost, complete, $2,112,540.

Portland to Point Pleasant.

Diameter, 14 feet. Slope, .000167. Capacity, 260,000,000 gallons daily.

	Total cost.	Length.		Cost.	
		Feet.	Miles.	Per Foot.	Per Mile.
Aqueduct	$14,220,000	208,200	39.43	$68 30	$360,000
Tunnel	2,200,000	29,500	5.59	74 60	394,000
Steel pipe	1,730,000	11,200	2.12	154 00	816,000
	$18,150,000	248,900	47.14	$72 90 (Average.)	$385,000 (Average.)

Point Pleasant to Philadelphia.

Diameter, 14 feet. Slope, .000167. Capacity, 260,000,000 gallons daily.

	Total cost.	Length.		Cost.	
		Feet.	Miles.	Per Foot.	Per Mile.
Aqueduct	$7,990,000	130,600	24.73	$61 20	$323,000
Tunnel	2,695,000	38,400	7.27	70 20	370,000
Steel pipe	745,000	4,700	0.89	158 50	837,000
	$11,430,000	173,700	32.89	$65 80 (Average.)	$347,000 (Average.)

Expenditures Necessary to Put the Present Works into Proper Condition.

Fairmount Pumping Station.

River wall at Fairmount forebay	$16,500 00
Roof and improvements to Fairmount western pump house	20,000 00

Spring Garden Pumping Station.

Repairs to Cramp pumping engine No. 7	5,000 00
Repairs to Holly pumping engines Nos. 2 and 3	16,500 00
Repairs to Gaskill pumping engine No. 11	5,000 00
Building conduits and filling forebay	25,000 00

Belmont Pumping Station.

House for Worthington pumping engine No. 4 and for housing additional pumping engines	25,000 00
Repairs to Worthington pumping engines Nos. 1, 2 and 3	3,000 00
Additional pumping machinery	75,000 00

Queen Lane Pumping Station.

Relaying suction mains and building new pump well	35,000 00
Tunnel and coal shed	36,000 00

Roxborough Pumping Station.

Repairs to Worthington pumping engines	1,500 00
Total	$263,500 00

As the labor at the stations will be furnished by the Department, it is not included in the above estimates of cost.

Fairmount and Flat Rock Dams.

Without more knowledge of the interior condition of the dams at Fairmount and Flat Rock, it is not possible to approximate the cost of repairing them, and, therefore, no amount is allowed in the above estimate of cost for this work.

Additional Mains for the Distribution System.

Belmont district	$372,000 00
Roxborough district	535,000 00
Queen Lane district	440,000 00
East Park district	770,000 00
Frankford district	650,000 00
	$2,767,000 00
Mains to connect Fairmount pumping station with East Park reservoir, and alterations in pumps (approximately)	260,000 00

Meters.

Repair shop and testing plant	$15,000 00
Tools, etc.	5,000 00
Purchase of meters	80,000 00
Total	$100,000 00

APPENDIX V.

Mechanical Analysis of Sands.

	Effective Size, m. m.	Uniformity Coefficient.
Cape May beach sand	.38	1.9
Delaware bar sand	.35	2.1
Gloucester sand—fine	.33	2.1
Bar sand	.30	2.5
Bank sand—Rancocas creek	.27	2.3
Cape May beach sand—fine	.24	1.5
White Jersey sand	.23	2.8
White sand—Gloucester	.24	3.0
Delaware bar sand—fine	.20	1.8
Gloucester sand—rough	.35	9.0
Jersey gravel—Rancocas creek	.16	4.4

"Effective size" designates the diameter of a grain of sand, 10 per cent. by weight of all the grains of the sample being smaller and 90 per cent. being larger than itself.

"Uniformity coefficient" designates the ratio of the size of a grain which has 60 per cent. of all the grains finer than itself to the size which has 10 per cent. finer than itself; if all grains were of equal size this coefficient would be unity.

All the above sands would require washing before being used in filter beds—the Cape May beach sands, to remove the salt; the bar sands, to remove the fragments of bark and finely-divided organic matter; and the bank sands, to remove the loam and clay mixed through them.

The Cape May sand is the best, but most expensive sand. The Delaware bar sand can be secured at a reasonable price, and, with proper selection and washing, would prove well adapted for purposes of filtration in the slow filters. The rough Gloucester sand, with screening and washing, would be valuable both for filter sand and for making concrete.

...m 1889 to 1898 inclusive.

	"i"		Net Earnings, or Excess of Gross Earnings over Expenses.	
Total.	Extensions.	Total Expenditure.	Amount.	Per Cent. of Earnings.
$708,847 53	$605,658 57	$1,314,506 10	$927,493 75	41.37
712,497 37	280,866 92	993,364 29	1,387,673 41	58.30
781,227 83	749,066 21	1,530,294 04	970,408 69	38.82
814,332 89	558,124 42	1,372,457 31	1,261,998 71	47.91
...,121,555 91	1,471,834 90	2,593,390 81	80,884 43	3.02
1,677,081 03	1,235,775 01	2,912,856 04	—153,225 45	—5.55
1,509,902 97	387,322 23	1,897,225 20	932,631 97	32.97
1,311,338 57	514,272 32	1,825,610 89	1,053,522 37	36.58
1,354,642 90	310,510 31	1,665,153 21	1,306,204 31	43.96
1,360,220 19	135,776 66	1,495,996 84	1,569,669 02	51.22

...ary supply and service mains; meters of all kinds, large valves, stops and ...enses of purveyors' offices, and lead service pipes laid by the City from main to

..." Expenditures for construction and repair shop include salaries of Superin... ...achinists, blacksmiths and all employees at shop; shop castings, including ...or fire hydrants, small stops, stop-box frames and covers, and grate bars; ...ine and miscellaneous castings, brass castings used in connection with the ... wrought iron and steel, other materials, and expenses of pattern shop.

..." Expenditures for office include salaries of Chief and assistants, Chief Clerk ...ants, Chief Inspectors and nineteen inspectors, four draughtsmen, assistant in ...distribution, and all other office employees; also office expenses, stationery and ...' supplies.

..." Expenditures for extensions include new work for which special appropria... ...made; including, in general, new pumping stations or engines, boilers, reser... ...kes, mains, etc.

REPORT

OF THE

Board of Water Commissioners

TO THE

Select and Common Councils

OF THE

CITY OF READING, PA.,

PERTAINING TO THE

PURIFICATION OF THE WATER SUPPLY BY

FILTRATION,

—INCLUDING—

The previous reports of the Board on the subject, the report of Superintendent and Engineer Emil L. Nuebling and Consulting Engineer Allen Hazen. Also recent opinions upon Filtration by Prof. Erastus G. Smith, Prof. Wm. P. Mason and Rudolph Herring.

FEBRUARY 28, 1898.

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FEBRUARY 28, 1898.

READING, PA.:
W. ROSENTHAL, CITY PRINTER, 710 PENN STREET.

REPORT

OF THE

Board of Water Commissioners

Relative to the Filtration of the Water Supply.

To the Honorable the Select and Common Councils of the City of Reading, Pa.:

GENTLEMEN :

Following the preliminary report pertaining to the purification of the city water supply by filtration, submitted to your honorable bodies under date of Oct. 11, 1897, we beg to present herewith our conclusions upon the subject, together with an extract from the Annual Report of the Board for 1895–96 relative to filtration ; also the report made by our Engineer and Superintendent, Mr. Nuebling, and Consulting Engineer, Mr. Allen Hazen, which report includes results of experiments and examinations made with the waters from the various sources of supply ; also covers in detail all technical questions pertaining to the problem. We here suggest to the reader, who wishes to study the subject, that before reading the conclusions of the Board, he read first the extracts referred to, the preliminary report, and the report of the engineers. This will afford a clearer insight into the whole subject.

The purification of the water supply has been a problem which has frequently received the consideration of this Board, and until the appointment of your Special Committee on Filtration, to urge us to action thereon, we have hesitated to make any recommendations definitely favoring filtration, principally because of the great cost attending both the installation of filtration plants and the expense of operating them as applied to our water works system. Another question considered was: Is the water supplied impure to a degree to seriously endanger the life and health of the citizens? And another, will the majority of our citizens approve of an expenditure of $300,000.00 for filtration in view of the fact that there is no constant serious contamination and the waters nearly always clear.

In our observation of cities filtering water, it was learned that scarcely any have had water in its crude state of such

uniformly good character as that of Reading, and that there are many large cities using unfiltered water which is contaminated to a vastly greater degree than any of the waters supplied our people. In recent years, however, the filtration of public water supplies has received greater consideration by water works officials, and while many cities are not filtering the water supply to-day, it is not because it is deemed unnecessary, but because the cost is most frequently a bar to the construction of the necessary plant.

Since the germ theory of diseases has attained such prominence as an explanation of the cause of disease, and scientists have conclusively proven its transmission with water into the human system, we can no longer ignore their claims that impure drinking waters are frequent and potent causes of sickness and death to the consumer; and the water works official of to-day must conclude that his most important duty lies in making every effort to furnish the consumer with water free from dangerous impurities. Nor is the bacterial quality only to be considered. Clear sparkling and palatable water will be demanded by the people.

It is, therefore, to filtration we must look to secure these results, and however great the cost, it is but proper to consider health and life paramount thereto. We believe that this sentiment will prevail, and that the next ten years will witness filtration in use in nearly every progressive city in this country.

Recognizing the fact that, with the constantly increasing use of the Maidencreek water, our citizens are exposed to the dangers of typhoid fever (by reason of its large and uncontrollable drainage area), and that the waters of the Antietam supply will be, by filtration, freed from the occasional objectionable taste and odor from vegetable growths therein, we recommend that the entire supply be filtered as early as practicable, first the Maidencreek supply, next the Antietam, the Bernhart and the Egelman, and we further recommend that the system known as *Slow Sand Filtration* be adopted as recommended by our Engineers, Mr. Nuebling and Mr. Hazen, in their report herewith.

In determining upon a system, we have considered first, the patented system of the Penna. Sanitation Co., somewhat similar to that in use for filtering sewage in this city. Second, the mechanical systems of rapid filtration with the use of coagulants. Third, Slow Sand Filtration. Each of which is discussed in detail in the report of the Engineers and their merits and demerits fully set forth.

The Penna. Sanitation Company submitted plans to filter the Maidencreek water by providing for a steel or iron structure

erected on the inside slope of the embankment and on the bottom of the Hampden reservoir, and for the Antietam on the front of the wall or breast of the dam, designed somewhat similar to the sewage filtration beds built by that company for this city.

The representatives of this company have on several occasions during the past three years appeared before this Board to urge consideration of its system to filter the water supply. Up to the time of the appointment of your special Committee we declined to take up the subject with them, because at that time we considered the principles upon which the system was designed and constructed as wrong, and not calculated to insure a high efficiency in purification, and because its construction was illy adapted to our system, and we doubted whether the steel structure would prove durable under the exposure to air and moisture to which it is subject. After the company had first submitted its plans to your special Committee, this Board was asked to give them consideration, which we have done very fully and are thus forced to put upon record what before was our private judgment.

It has been apparent that this company has some friends in this city who are disposed to favor its system. For this reason we have given the plans submitted careful investigation, so that the claims made for it would be fully understood, and its shortcomings fully explained. Not only has our own judgment been passed, but that of our Engineer, Mr. Nuebling, and Consulting Engineer Mr. Hazen, whose explanations of the system are fully made in their report, and we ask your honorable bodies to give them careful study. We have also had other disinterested water works engineers to visit the sewage plant in this city to learn the principles of its construction and operation, and their expressions we can assure you were not those of approval. We are also advised that the officials of several other cities in this State have been during the past year studying the system of this company, and we have yet to hear of its adoption by any of them. Director Thompson in a report on the filtration of the Philadelphia supply, states he has visited nearly all large filter plants in this country, (and we know he made an inspection of the Sanitation Co. plant in this city)and strongly recommends *Slow SandFiltration.*

The "Engineering News," a journal devoted to the discussion of all important engineering problems before the people, in its issue of Jan. 27th, 1898, has published a detailed report upon the sewage plant in this city, and in an editorial upon the system attacks its efficiency and the high rate of filtration

claimed. The aeration feature upon which the company places so much stress is shown to be of no great value, particularly as a filter for water, and closes the article as follows :

"In conclusion we are compelled to say that in our opinion the claims made for this plant are not proven ; that the rate of filtration is many times beyond the capacity of the plant to perform ; that the expense involved in elevating the upper bed is not warranted by results shown ; and that the City of Reading could have built for less money filter beds that would have done far more work than can ever be expected from these."

With due deference to the opinion of the friends of the system of this company, we regret that their views cannot be sustained by our investigation thereof. We therefore are obliged to reiterate our previous opinion that if the interests of the city are to be regarded, this system should be considered as an experiment, and no money risked thereon.

Several systems of mechanical filtration have also been investigated, principally small plants, and operated by private water companies. It is deemed advisable not to recommend the adoption of any of these systems brought to our attention. They are all costly to maintain if a good bacterial efficiency is desired. All of the systems have expensive machinery to maintain and in time to replace. We regard the conclusions of Mr. Nuebling and Mr. Hazen, relative to their application to our system, as sufficient reasons for declining to recommend mechanical filtration.

Slow Sand Filtration has been in continued use in this country and Europe for a period of over fifty years. Under all recorded tests, and under all conditions it has shown the highest efficiency. It has been proven the most durable in construction, and its efficiency most successful. Abundant testimony could be submitted on these points. Our observations on this subject lead us to the conclusion that there has not yet been anything devised which will equal it, because its basis is founded upon natural principles ; it filters water as nature does through the earth, and all other systems are only attempts at imitation thereof and therefore make-shifts and largely experimental. The first cost of construction for Slow Sand Filtration is greater under ordinary conditions than the mechanical systems, or that of the Penna. Sanitation Co., but in cost of operation and durability this is more than made up.

In construction, the filter beds under this system resemble and have that permanency which is found in storage reservoirs; when once built they will require no expenditures for main-

tainance except the cost of scraping and washing the sand from top of the beds. We have through correspondence and personal contact with able and experienced water works men, and experts on filtration, made numerous inquiries, and discussed this subject, and found nearly all agreed that slow sand filtration is to-day the only system which can be safely recommended.

Director Thompson of Philadelphia in his recent report to Councils, on the water supply, under date of October 7th, 1897, says:

"From all the information which I have been able to gather from abroad and in this country, it appears that slow sand filtration has proven a success, and is no longer considered an experiment. It is the only system in successful practical use for purifying the water supply of any of the great cities of the world. In several instances, as at Antwerp, for example, where it was originally intended to supplement sand filtration by other methods, sand filtration alone has proved sufficient for the purpose, and the supplemental methods have been abandoned. From all the research which I have made in the matter, I am of the opinion that the City of Philadelphia should adopt a method of slow sand filtration. Although this system is considered more costly in construction, the filter bed, if well designed and properly cared for, is almost indestructible, and involves practically no expense for repairs. The expense of operation is practically confined to the cleaning of the filters, and is much less than that attending any system of mechanical filtration."

Jno. C. Trautwine, Chief Engineer of the Bureau of Water, in same report says:

"If Councils are determined to select a system without experiment, let it, by all means, be the old-fashioned, slow, or so-called 'natural' sand filtration, which has, at least, demonstrated its usefulness by many years of successful use on an enormous scale in London and other European cities."

We, therefore, have no hesitancy in saying to our people it is the best, and that if filtration is wanted, it should be adopted and put in service without delay. In support of our decision and for the information of our citizens studying this subject we have appended to this report the letters and recent opinions of the following eminent authorities, viz.:

Prof. Erastus G. Smith, Prof. of Chemistry of Beliot College, Wisconsin.

Prof. W. P. Mason, of the Polytechnic Institute, Troy, N. Y.

Rudolph Herring, C. E., Consulting Engineer, New York.

These are taken by permission from the aforesaid report of Director Thompson on the Philadelphia water supply and filtration, all of which have an important bearing on the conditions existing in our city. They afford valuable information for our citizens on the subject and careful study is suggested.

As the Maidencreek and Antietam are first to be filtered, we give here comparative cost thereof; the cost of the other sources can be seen in the statement of the Engineers.

The cost of a Slow Filtration Gravity Plant for the Maidencreek of 9,000,000 gallons daily capacity, and Antietam of 3,500,000 gallons, at the highest figure is $186,000 for the former and $5c,500 for the latter, or a total for the two of $236,500, as against $268,700 for Penna. Sanitation system, and $169,700 for the mechanical or rapid system. The great cost of the Sanitation Co. system here is because it is, as before stated, not well adapted to the existing conditions of these sources, more fully referred to in our Engineers' report.

The annual cost of operating the Slow Sand Filters for some years to come, exclusive of interest charges, for the Maidencreek is $2,500.00, and of the Antietam $2,625.00, or a total of $5,125.00, as against $5,345.00 for the Sanitation Co.'s system and $9,534.00 for the Mechanical system. There is thus shown that for a system of Slow Sand Filtratian for these two sources the cost would be $32,200.00 less than for that of the Penna. Sanitation Co., and $66,800.00 greater than the Mechanical system; and operating $220.00 less than the Sanitation Co., and $4,409.00 less than the Mechanical system If the plan to pump to the sand filters at Maidencreek be adopted, the cost of construction for Maidencreek and Antietam plants would be $77,700.00 less than that of the Sanitation Co. and $21,300.00 greater than a Mechanical system, and in operating $1,030.00 greater than the Sanitation Co., and $3,159.00 less than the Mechanical system. In these estimates on operation nothing has been figured for depreciation by corrosion, &c., of the steel structure of the Sanitation Company filters, painting and other care thereof.

Having now disposed of the problem with regard to the kind of filter, the means to raise money to install the system is the next important question.

The total cost to construct slow sand filters for the entire system is as follows:

Maidencreek gravity filter	$186,000 00
Antietam " "	50,500 00
Bernhart " "	44,900 00
Egelman " "	6,900 00
Total for all	$288,300 00

and the maintenance and operation, including interest charges, on the same would be as follows:

Maidencreek supply	$11,800 00
Antietam "	5,150 00
Bernhart "	3,870 00
Egelman "	570 00
Total	$21,390 00

In our judgment the cost of construction for the Maidencreek and Antietam filters can be provided for only by a loan, which would have to be authorized by the people, and as the people want to have some say on this question of filtration, let them decide it by voting on a loan of $225,000.00, which amount with the premium received on sale of bonds will install a system of slow sand filtration for these two sources of supply. The cost of filtering for the Bernhart and Egelman supplies can be provided for from the surplus revenue after the year 1900.

The cost of maintenance, operation and interest will have to be made up, in part, by increasing the annual water rates which will mean the restoration of the fifty cents taken off the hydrant charge a few years ago. Any increase of the city's indebtedness is usually looked upon by many with disfavor, and this Board feels the responsibility it has assumed in making a recommendation for a public improvement which involves such an increase of the debt. Pure and palatable drinking water, however, is something in which every citizen must have some concern, and he should know whether it is of sufficient importance to him to lend his aid in providing means to secure it.

Relative to the debt of the Water Department, we may explain that in January 1900 and 1902, $127,500 of the debt matures; provision has been made to pay this from the revenues of the Department; this would leave the net debt $405,000. In 1910 another loan of $75,000 matures, which is also provided for from the revenues. At that time the net debt will be less than $325,000, and not due until 1920. If the proposed loan of $225,000 is issued, by 1920 $165,000 thereof will have been provided for in the Sinking Fund. The balance of $60,000, added to the $325,000, will leave the net debt in 1920 less than

$380,000. This would be a very light debt on a water works plant, which will, at that time, be worth over $2,000,000. Let it be remembered that the water works system has cost to this date about $1,700,000, and this present debt of $405,000 is very small when we consider that the works was bought but thirty-three years ago, at a cost of $300,000, and bonds issued for that amount at the time of purchase. This sum of $1,700,000 represents the original cost of $300,000, the permanent improvements and extensions to the system since its purchase. Interest, maintenance and operation are not included. If the net debt is but $405,000 and the cost $1,700,000, the Department from its own revenues will have expended for these improvements about $1,300,000 in thirty-five years, or an average of about $37,000 per annum. To add $225,000 to the bonded debt for filtration, will in our opinion not add any burden to the water consumers, and if they want better water than we have to-day, let them vote for a loan to secure filtration, or make no further complaints about bad tasting or impure water.

Cities of the size and progressive spirit of Reading are continually spending large amounts for improvements to their water supply, and we can point to many spending relatively much greater sums than Reading.

In addition to the places already having filter plants, Albany, N. Y., has to-day a filtration plant under construction which is to cost nearly half a million dollars, while Pittsburg, Pa., Philadelphia, Pa., St. Louis, Cincinnati and many other cities have the matter under consideration. Reading will accomplish much if it can secure a filtration system without increasing the debt more than we recommend, viz : $225,000.

The argument may be made by some not familiar with the requirements of our water works system, that the total cost of filtration could be paid from the surplus revenues of the department. A careful inquiry into present and prospective needs, forces us to the conclusion to recommend the *Loan*, for no large surplus can be maintained unless the increase in water rates be made considerably greater than before mentioned. In 1898-'99 nearly $30,000 in each year will have to be placed in the Sinking Fund to meet a bonded debt of $57,500 maturing January 1900, which is unprovided for in the present Sinking Fund ; $20,000 for Section "2" of the Maidencreek Pumping Main and $8,000 for completion of Sedimentation Basins at Antietam. In 1899 $30,000 to the Sinking Fund as above, $20,000 to the Maidencreek.

In 1900 the 20-inch and 16-inch trunk line will have to be laid beginning at Centre Ave. and Amity streets, thence along

the route laid out on the distribution plan adopted by the Board to Fifth and Pine streets, at a cost of about $150,000.00.

The issue of a loan for this trunk line has been discussed by the Board during the past year, but since your honorable bodies have urged filtration by the appointment of a special Committee to confer with this Board, it has been decided that it would be the wisest policy to give filtration precedence and ask for a loan for that purpose, and defer the laying of the trunk line for two years and then endeavor to pay for it with the surplus revenue over a period of five years.

If filtration should be put into effect the increased cost resulting therefrom will add nearly $22,000 to the maintenance and interest account, which, with the ordinary requirements always to be provided for, will, we are convinced, prevent any large sum from the annual revenues being used for the installation of filtering plants at all the sources of supply.

In conclusion we wish to say that we have endeavored to present the subject to you as fully as possible, and in making up our conclusions have had in mind solely the best interest of our city.

We beg to add our expression of approval of the efforts and ability shown by our Superintendent, Mr. Nuebling, in his treatment of this subject as given in the joint reports of himself and Consulting Engineer Mr. Hazen, and further to add, that in Mr. Hazen the city has had the experience and knowledge of one whose opinions and recommendations will bear the scrutiny and command the respect of the best authority on filtration.

In order to bring the question to an issue without further delay, we will present for your consideration, immediately after the organization of the new Councils, the legislation necessary to provide for the loan, and authority to proceed with the work.

Trusting that our recommendation may meet your favor, we are

Very respectfully,

GEO. H. FELIX,
M. HARBSTER,
FRANK A. TYSON,
F. P. HELLER,
Board of Water Commissioners.

Reading, Pa., Feb. 28th, 1898.

ABSTRACT

From 31st Annual Report of the Board of Water Commissioners, 1895-'96.

ANTIETAM LAKE SUPPLY.

This source of supply remains in about the same condition as last reported. The water was in use during the year except at the time of the drought. The low condition of the streams and having to use the water which had been stored for some time, were cause for the musty or woody taste and smell noticed during this time. The reservoir was emptied and fresh water dammed to refill it, after which it was again put to use.

Of the lands adjacent to the reservoir and contaminating the water, the Hinnershitz Mill property; the Daniel Faust property; the Chas. Wentzel and Henry Schildt properties have been secured. The appropriation for 1895 for this purpose not being sufficient to pay all and receive title at once, they were secured and paid for in part, the title to be delivered in April, 1896, when the annual appropriation for 1896 would be available; possession to be given on July 1st, 1896. Until that time, therefore, no work to improve the condition of these properties and prevent the pollution could be commenced. Plans will be immediately prepared for the improvements calulated to free this water from dangerous contamination, and put into effect as early as possible. For the cost of each of these properties see statement in Superintendent's report.

Incident to the purchase of these lands, and before they were bought, there arose in the minds of your Commissioners the question of the filtration of this supply, and its results as compared with results to be attained by the ownership of portion of the drainage area.

The subject was given thorough consideration and investigation. The facts to be considered in discussing it are these:

1st—The source of the supply is from springs in a mountainous country, covering a total drainage area of 5.44 square miles, formed into several streams and collected in a storage reservoir of 101,000,000 gallons capacity, and piped by gravity 3 miles to the city; the character of the water, such as when free from the contamination from farm lands through which the streams

pass, makes it a most delightful, palatable and healthful drinking water, which with its high elevation and being capable of a daily service of about 3½ million gallons, proves it to be a very desirable source of supply.

2d—The contamination which this water receives is the drainage, in times of heavy rainstorms and freshets, from some of the barn yards and farm dwellings, located near the reservoir and along the streams, and causes a pollution of the water. This, and this only, affects the purity of the water with its resultant dangers to the health and life of our citizens. If we remove the cause of this danger (and prevention is always better than cure), no better water can be had.

3d—That at a certain period of some years this water developes a musty, woody taste and smell. This condition is found in many water supplies having their source in mountain springs and stored in quantity. While it is objectionable, it should cause no fear for the public health. It occurs at a time when the storage supply is being drawn upon, and is sometimes of very short duration, its disappearance being as sudden as its coming, apparently due to some process of nature. Physicians and chemists agree that it has no deleterious effect upon the human system. This condition therefore, should have no material bearing upon the question of the need of filtration. It is only periodical, is insignificant as affecting public health and its successful removal by filtration a very doubtful result.

In our search after knowledge upon the practical results of filtration, it was learned that a supply of filtered water is not without its objections; that filtration is not in all cases a success, and that it is admitted by many Water Works Engineers and Chemists, that the filtration of public water supplies is yet in its experimental stage and much yet to be learned to meet the conditions required to successfully make impure water absolutely pure and at the same time a palatable drinking water. Upon inquiry it was found that all or nearly all cities filtering water, were forced to do so because the character of the water at their command was such as to be totally unfit at any and all times for domestic use; that in many cases it was the only supply obtainable, and filtration the only possible means to secure water fit to use. The cities located along the murky waters of the southern states; those along the turbulent Missouri and Mississippi rivers and the polluted Ohio, and those depending upon the streams and rivers polluted with the drainage and sewage from the many manufacturing cities and towns of the

New England States, are forced to filtration as their only resource. The situation of Reading is an entirely different one.

Looking to the filtration of our Antietam supply from a practical standpoint, we are convinced that the conditions pertaining thereto are such that only mechanical filtration is feasible and with this a pumping plant to maintain all the advantages which the reservoir now affords. The cost of such a plant will be not less than $60,000.00, and at least $5,000 annually to operate it. The cost of the lands recently purchased has been $35,000.00, with $15,000.00 additional expended in this manner and $2,500 annually for care of the lands; with sanitary inspection maintained over the few farms yet remaining on the water shed; with proper and friendly efforts, exerted with the owners, nuisances would be abated, and all pollution would be prevented, and the water delivered to our people in its normal condition, free from impurities and always palatable, and at less cost than filtration. It is admitted by some of our expert chemists that the water from mountain streams, free from dangerous contamination, is always more desirable than filtered water, and that the ownership or control of the water shed to prevent such contamination is far preferable to any system of filtration.

Another practical question to be considered was: If the Antietam supply be filtered, why not the Bernhart? (The conditions are similar, though in not so marked a degree in the matter of pollution.) And why not the Egelman and the Maidencreek supplies? Should only one-third of the city be supplied with filtered water and two-thirds not? With the arrangement of our distribution system, either one of the different sources at times must be used in the territory supplied by the other, which would mix the filtered water of the Antietam with the unfiltered water from the other sources, thus for the time nullifying the filtration of the Antietam supply.

The thought of a plan, for entire filtratian, suggests an expenditure of at least $250,000.00; increased fixed charges annually of $40,000.00, and increased water rents as a consequent result.

After a careful consideration of the entire subject, the conclusion was reached, that the conditions affecting the Antietam supply were such as to make any effort at filtration very doubtful of success, and that until the entire supply can be filtered, any expense in this direction would be unjustifiable; that the ownership of such of the lands as most seriously pollute the water, a systematic sanitary inspection maintained over all the water shed and the care of these lands under proper supervision

and direction, together with a proposed system of sedimentation and aeration, by the construction of a series of small dams and weirs along the streams above the reservoir, will afford the cheapest and most permanent plan, and preserve the water in its natural state and be free from any dangerous or objectionable contamination.

Acting then on these conclusions, the properties hereinbefore mentioned have been purchased. The improvements will go on as fast as funds will allow, and no effort will be spared to eradicate the pollution of this supply.

We wish to add that an important advantage in owning the land in question is that the many small springs scattered among the hills can be opened up and drained into the streams instead of the meadows and low-lands now soaking up the water, thereby increasing the flow of the streams, we believe, to the extent of a half a million gallons daily.

PRELIMINARY REPORT OF THE

Board of Water Commissioners,

RELATIVE TO THE

Filtration of the Water Supply.

PRESENTED OCTOBER 11, 1897.

To the Honorable the Select and Common Councils of the City of Reading ·

GENTLEMEN :

By resolution approved June 1, 1896, your honorable bodies appointed a special Committee of six members of Councils "to act in conjunction with the Water Board to look into the matter of filtration (of the water supply) and report to Councils as early as possible, giving probable cost of filtering that supply (Antietam), with a view of filtering our total supply if advisable."

Our Board received official notice of this action on July 7, 1896. The first joint meeting of the Committee and the Board was held on July 21, 1896. Meetings were subsequently held on February 23 and April 15, 1897.

The special Committee expressed to the Board that it was the judgment of the members of Councils as well as many citizens, that the condition of our water supply was such as to require purification by some method of filtration, and, as the resolution states, Councils wanted some information as to the cost of filtration.

During the discussion of the subject it was developed that the members of the special Committee had a very limited knowledge of the methods of filtering large supplies of water, and were not familiar with the several systems in use, other than that of the Pennsylvania Sanitary Sewerage Co. filtering sewage in this city. This being the case, the members of the Board who had given the subject considerable prior study, determined that if the filtration of our water supply was to be *seriously considered* by the special Committee and the Board, the Committee should be given the opportunity to inspect the plants or systems in operation in other cities, to secure the information so necessary to an intelligent disposition of this very important subject.

Your honorable bodies were then asked for authority for such inspection, which was granted by resolution approved June 30, 1897.

Accordingly visits were made to Far Rockaway, L. I., Poughkeepsie, N. Y., and Lawrence, Mass., each operating a system constructed upon the principles of what is commonly designated "Natural Sand Filtration" (by some called Slow Sand Filtration), which consists of underdrained beds of sand built upon land, and the filtrate drained into pump wells or reservoirs as required. These beds are usually designed to filter from two to four million gallons per acre of filtering area in 24 hours, which slow rate has proved to effect the highest degree of purification.

At Westerly, R. I., and Long Branch, N. J., the systems of the New York Filter Mfg. Co., the former operating their Open Gravity system and the latter their Pressure system of Mechanical Filtration.

At Atlantic Highlands, N. J., operating the Continental Filter Co. Pressure system of Mechanical Filtration.

At Elmira and Niagara Falls, N. Y., the Jewell system of Open Gravity Mechanical Filtration.

At West Reading, Pa., operating the Warren system of Mechanical Filtration.

At Wilmington, Del., a specially designed system by the United States Filtering and Purifying Co. This is the only plant the company has in use, and might be termed Mechanical Upward Sand Filtration, using metallic iron as a coagulant, and has an aeration scheme as a special feature, and is designed to filter somewhat less rapidly than the regular mechanical filters.

At Reading, Pa., the plant of the Pennsylvania Sanitary Sewerage Company, filtering sewage. This system consists of elevated iron or steel structure, supporting beds of sand, the water after passing through these beds dropping through air a distance of ten feet to a reservoir. This aeration feature differs from that of any other system and is recommended by the company as of special consideration. The company has no water filtration plant in use, but at the recommendation of your special Committee has placed drawings and specifications before this Board, showing the same principles applied to water filtration, except that the additional or lower bed used for sewage is dispensed with. There are no mechanical devices used in its operation and its principles of construction are nearer that of "Natural Sand Filtration," although the rate claimed is much more rapid than usually adopted in the practice of "Natural Sand Filtration" construction.

In the foregoing we have given as concisely as possible all the systems visited and about all the different kinds in use.

All the systems termed "Mechanical" are so called because the cleansing of the sand or filtering medium is done by mechanical devices operated by steam power. All of these use either alum, salts of iron or milk of lime as a coagulant, thus securing rapid sedimentation. This with the frequent washing of the filtering medium, made possible by the mechanical devices, secures a very rapid rate of filtration, and in some systems satisfactory results as to purification. These systems are by some called "Rapid Filtration." By reason of their ability to filter rapidly, the area required for filtering a given quantity daily is very small as compared with that of the "Natural Sand Filtration Systems."

In the "Natural Sand Filtration Systems" the rate of filtration is kept low, and the water passed through thick beds of sand (in imitation of water passing through natural formations of earth and sand), thus securing the highest degree of purification, at the expense of increased area. Neither aeration or coagulant is used to secure the purification of the water.

The cost of these different systems might be recorded in this communication, but as the statements would require a great deal of time and space they are dispensed with. The various conditions and problems affecting our supply, as compared with that of other cities, prevents intelligent comparison with the cost of a system here. Such figures therefore would be uninteresting and serve no purpose. We will reserve for a future communication the question of cost for a system for our city.

At this point we wish to say that this Board has not been oblivious to the needs of the city in the matter of the purification of its water supply. The various engineering problems connected with the study of the several systems of water purification have been continuously in view.

Long before the appointment of your special Filtration Committee the Board and its Engineer have had frequent consultations upon the questions involved in the preparation of plans for the purification of our entire supply. The varied conditions affecting our supply system, the several classes of service to be cared for, the various results which may be secured from different systems of filtration, and more particularly the important bearing the efficiency of purification has upon the cost of construction and operation, make the subject one, which, if the interests of the city are to be properly protected, cannot be hastily disposed of. By reference to the annual report of

1895–'96 it will be found filtration was given serious consideration prior to the purchase of some of the lands in the drainage area of the Antietam supply. Since that time a careful study of the systems and experience of other cities has been made, and the methods adopted by them to secure successful results have been learned. All of which places the Board in a position to judge what can and should be done in the matter of the purification of Reading's water supply.

What was learned on the recent visits of inspection by the Board and the special Committee, was but largely a repetition to the members of the Board. The knowledge secured was, however, valuable to the Committee, and we are glad to say the keen interest shown by the members in the several systems will aid them materially in the discussion of the subject when brought before your honorable bodies. The money expended for this inspection was wisely given, for there can be no question that it will be of material benefit to the city.

When in February, 1897, the Penna. Sanitation Co., at the suggestion of your Committee, and without any request from this Board, presented plans and specifications for filtering the Maidencreek and Antietam supplies, the situation became such as to make it evident to this Board, that the question of filtration would have to be met in a business way, and proceeded with in such a manner as to prevent the adoption of a system without a thorough knowledge of its efficiency, economy and practicability as applied to our water works system. The conclusion was reached that no system for the purification of the water supply should be put upon the city without knowing what it would do, and in securing that knowledge the results of efficiency and practicability of the several systems must be passed upon by expert authority on filtration of public water supplies, acting solely in the interests of the city, and not for any particular system or company, and whatever system would meet the standard of efficiency and economy required by the Board and its expert, would be recommended to your honorable bodies. Having then assumed this position and having before us the plans of the system of the Penna. Sanitation Co. to be disposed of, we at once (February 15, 1897) referred the said drawings to our Superintendent and Engineer, Mr. Nuebling, with instructions to prepare a report upon the whole subject of filtration. At the same time it was agreed to appoint a consulting engineer of recognized ability to act with him. The scope of action and authority given Mr. Nuebling, will be best explained in the following resolution passed by the Board at the time, viz.:

"WHEREAS, Councils have appointed a special Committee to confer with this Board relative to the filtration of the water supply of the city, and said Committee having appeared before the Board on two occasions, and recommend that some plan for filtering water be adopted and put into service and ask that the Board present a report to Councils upon the subject; and

"WHEREAS, The Penna. Sanitation Co., of Philadelphia, is the owner of a patented system of filtration, and has, of its own volition, presented for our consideration plans and specifications for filtering the Maidencreek water at the Hampden reservoir, and the Antietam supply at the Antietam Lake; and

"WHEREAS, The subject of filtration having been under consideration by this Board for the past two years, and being one of such magnitude, and serious concern as to cost as well as successful results, it is deemed advisable that sufficient time be taken to allow the question careful study and research as well as experiment; it is therefore

"RESOLVED, That this Board proceed to the consideration of the entire subject of filtration of the water supply by a thorough investigation of all the systems of filtration, with a view to securing the best attainable method in accordance with the most advanced thought and experience upon the subject, and that, preliminary to making a report thereon, the plans and specifications of the system submitted by the aforesaid company be referred to the Superintendent and Engineer for examination and report to this Board; that he is especially instructed to report upon its practicability and efficiency as applied to our water system, examine and compare same upon all points with other systems; that in connection with the Board he investigate other systems, and ascertain the experience of other cities, make experiments, collect such data upon the subject as in his judgment will bear upon the successful and economical filtration of such parts or the whole of the water supply; that he is authorized to visit other cities, at the expense of the department, whenever expedient to secure necessary information, and that he report to this Board from time to time the course of his procedure; and further

"RESOLVED, That at the proper time a consulting engineer of recognized ability on filtration of water supplies be employd to advise and consult with the Superintendent and Engineer on this subject."

Accordingly on the 6th of March, 1897, we engaged as consulting engineer Allen Hazen, C. E., of N. Y., an authority of national reputation on the filtration of public water supplies

and water works practice generally. One of the first steps taken was to ascertain what results could be secured, chemically and bacterially, and as well at what rate the water of the several sources could be safely filtered, and from these results calculate the cost per million gallons to filter our supply.

For this purpose our Engineer, Mr. Nuebling, planned and erected two experimental filters, each 3 feet in diameter; one built upon the principles of natural sand filtration, the other upon the principles given in the drawings and specifications submitted by the Penna. Sanitation Co. In the month of April, 1897, we placed in charge of these filters Mr. F. S. Hollis, a competent chemist and bacteriologist, formerly in the employ of the Massachusetts State Board of Health, and now acting biologist of the Boston Water Department. For a period of two months daily examinations of the waters from the several sources were made, under all the varied conditions of our supply during that time. All such tests were made as were deemed pertinent to an intelligent study of the question of filtering our water supply.

Our Engineer, Mr. Nuebling, is also well versed on the subject, and with the aid of such talent as above, we feel satisfied that we are in good hands, and that nothing will be left undone to secure entirely satisfactory results.

Particular instruction was given our Engineer to design and submit plans and costs of systems of natural sand filtration and of mechanical filtration, in order that their cost and efficiency may be studied in comparison with the patented system of the Penna. Sanitation Co.

The work is necessarily slow, and having to be done in connection with the other improvements in the hands of Mr. Nuebling, has been delayed longer than was our intention. As the work is now well in hand, we expect within the next two months to receive the report of the Engineers with complete drawings, estimates, &c.

It is not our purpose at this time to make any argument for or against filtration, but as soon as the report of the Engineers is received, we will present to your honorable bodies the subject in such shape as to afford you the opportunity for thorough inquiry, together with such recommendations as in our judgment will be for the best interests of the city. When all the data is submitted to you, we hope to place it in such light as to prepare you for an early decision as to whether we shall have our water supply filtered or not, and in what manner it should be done.

We submit herewith an ordinance to make an appropriation of $1,500, to pay the expense necessary for the experiments and services of consulting engineer, and recommend its passage.

Respectfully submitted,

M. HARBSTER,
F. P. HELLER,
GEO. H. FELIX,
FRANK A. TYSON.
Board of Water Commissioners.

READING, PA., Sept. 27th, 1897.

REPORT

ON THE

Filtration of the Water Supply

OF THE CITY OF READING, PA.

—BY—

EMIL L. NUEBLING, *Superintendent and Engineer.*
ALLEN HAZEN, *Consulting Engineer.*

To the Honorable the Board of Water Commissioners of the City of Reading, Pennsylvania :

GENTLEMEN :

In accordance with your request, we beg to submit the following report upon the filtration of the water supply of the City of Reading, and the feasibility and cost of accomplishing the same by various methods:

SOURCES OF SUPPLY.

The City of Reading is supplied with water from five sources. The first source consists of certain springs in the neighborhood of the Hampden reservoir, which yield a limited amount of water of very satisfactory quality. This supply does not require filtration.

The second or Egelman supply is from an impounding reservoir, holding 2,500,000 gallons, upon a water-shed of 0.54 of a square mile. There are several houses upon this water-shed. The geological formation of this drainage area consists of about 35 per cent. of Potsdam sandstone and 65 per cent. of gneiss. About one half of the drainage area is woodland. The quality of the water is ordinarily good, excepting that algae growths at times give rise to unpleasant tastes and odors, and after heavy rains the water becomes muddy. The Egelman reservoir supplies the High Service District.

The third source of supply is from the Bernhart reservoir, with a capacity of 42,000,000 gallons, supplied by a drainage area of 2.56 square miles. There are about thirty houses on this water-shed. The geological formation of this drainage area consists of 80 per cent. of Potsdam sandstone and 20 per

cent. of gneiss, and fully 30 per cent. of it is woodland. The water is considerably harder than the Egelman, and suffers occasionally from mud and algae growths. The water receives, and is made much harder by the water of, several springs, which are much harder than the surface sources. This excess of hardness is apparently due to contact with subterranean deposits of limestone. The capacity of the pipe line from this reservoir to the city is 2,500,000 gallons per day, and the elevation is such that it just serves for the supply of that part of the city lying below a contour of 270, and known as the Low Service District. At dry seasons more water is required in this district than can be supplied from the Bernhart water-shed, and the deficiency is at present made up with water let down from the Intermediate Service; but it is the intention, after certain changes in the pipe line shall have been made, to supply this deficiency and the natural increase in consumption in this district with water pumped from Maidencreek to the Bernhart reservoir direct.

The fourth source of supply is the Antietam reservoir, holding 101,000,000 gallons, supplied with water from a drainage area of 5.44 square miles. There are about eighty houses upon this water-shed. Your honorable Board has within the last few years purchased those places upon the water-shed which were nearest to the reservoir, and which from their locations probably contributed in greatest measure to its pollution. The geological formation of this drainage area consists of 25 per cent. of Potsdam sandstone and 75 per cent. of gneiss. The water from this water-shed is quite soft. The water in this reservoir is occasionally muddy, and has algae growths, which make it quite unpleasant in taste and odor. The conditions of the water in the Antietam reservoir will be considerably improved by works now under construction, namely, a series of small dams along the streams supplying the reservoir, which dams are to be so constructed as to aerate the water as it flows over them. The capacity of the present pipe line from the reservoir to the city is 3,500,000 gallons per day, and the elevation is such as to allow its use without pumping in the Intermediate Service.

The fifth source of supply is Maidencreek. Water is pumped from this creek at a point where its drainage area is 210 square miles. There is no storage reservoir on the creek. The geological formation of this water-shed consists of 70 per cent. of slate, 21 per cent. of limestone and 9 per cent. of other formations, the larger part of the limestone being on the water-shed of Willow creek, a tributary entering Maidencreek about half

a mile above the pumping station. There are several small villages and institutions upon the water-shed of Maidencreek, some of which are sewered, and the sewage is discharged untreated into the creek or its tributaries.* The water of Maidencreek is considerably harder than that from the Antietam and Egelman reservoirs. It is not subject to the disagreeable tastes and odors resulting from algae growths. It is muddy after heavy rains, and the discharge of sewage into the streams renders the use of this water in its raw state more or less injurious to health, and objectionable.

REQUIREMENTS OF FILTRATION.

The problems presented are: (1st), the removal of the mud from all of the waters after heavy rains; (2d), the removal of the tastes and odors resulting from algae growths from the waters of the Antietam, Bernhart and Egelman reservoirs; and (3), the removal of the bacteria which are or may be injurious to health, discharged into the Maidencreek by the above mentioned sewers or other sources of pollution, and of similar germs from the reservoir waters, in case such germs are present or should be introduced from the inhabitants living upon the respective drainage areas.

The disease, which is believed to be most frequently caused by polluted water supplies, and the presence of which in a city is most characteristic of such pollution, is typhoid fever. Typhoid fever is caused in other ways than by polluted water supplies, but its continued and excessive presence in a large city, unless otherwise explained, is an indication of such pollution, and in case of known pollution, can be taken as an approximate index of the damage resulting from it, being far more reliable in this respect than other diseases also caused by pulluted water, but whose occurence is more dependent upon other causes not connected with the water supply.

The following table shows the number of deaths from typhoid fever in Reading for the last twenty years, with the estimated population, and the death rates from this cause for each 10,000 living. These numbers have been compiled from the printed records of the City Board of Health by adding together the deaths reported for each month of the year, and deducting cases of burials where the death did not occur in the

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*See Appendix B.

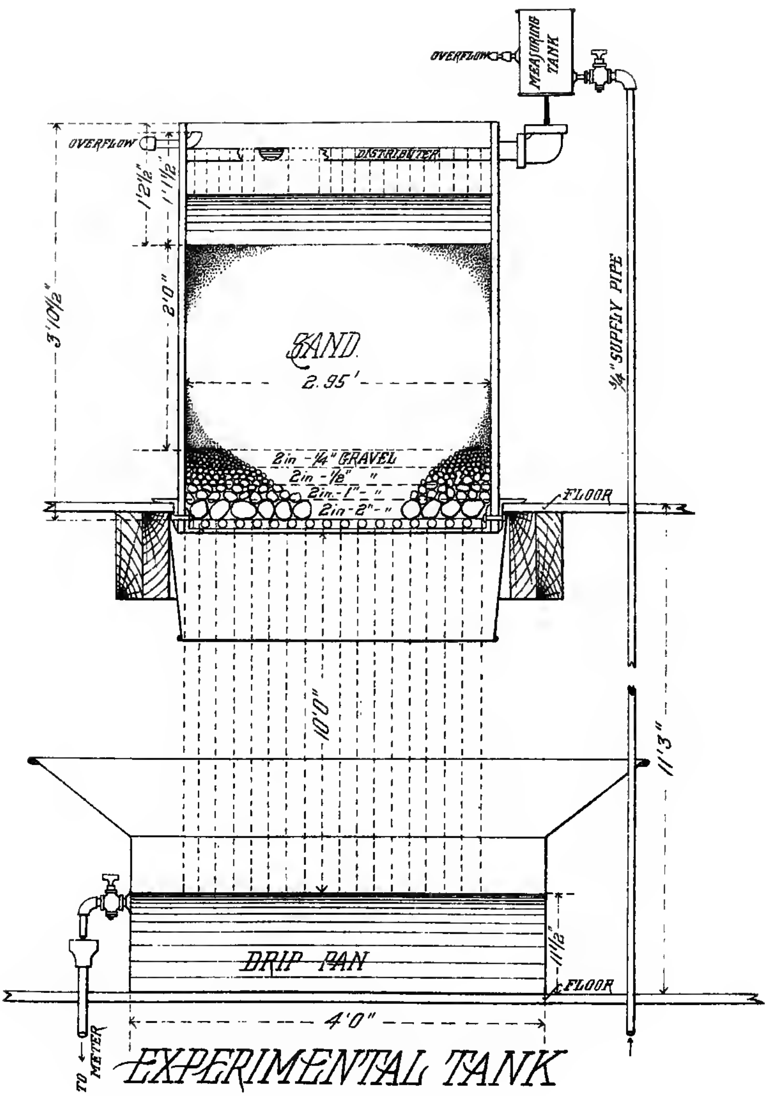
city. The figures thus differ from the yearly totals in the published reports :

DEATHS FROM TYPHOID FEVER, READING, PA., 1877 TO 1896.

Year.	Estimated Population.	Deaths from Typhoid fever.	Deaths from Typhoid fever for each 10,000 living.
1877	39,650	10	2.52
1878	40,780	13	3.19
1879	42,000	2	0.48
1880	43,278 U. S. Census	10	2.31
1881	44,540	18	4.04
1882	45,900	16	3.49
1883	47,300	8	1.69
1884	48,800	13	2.66
1885	50,330	14	2.78
1886	51,950	22	4.23
Average for ten years, 1877 to 1886, inclusive,			2.74
1887	53,550	19	3.55
1888	55,200	24	4.35
1889	56,880	27	4.75
1890	58,661 U. S. Census	32	5.46
1891	60,400	29	4.80
1892	62,260	28	4.50
1893	64,200	26	4.05
1894	66,200	30	4.53
1895	68,300	28	4.10
1896	70,400	36	5.11
Average for ten years, 1887 to 1896, inclusive,			4.52

These figures show that the typhoid fever death rate in Reading has been slowly increasing, and, although not yet excessively high, is considerably higher than the rate in most American cities having thoroughly good water supplies, and it appears probable to us that the increase in the rate has been connected with the increased use of water from Maidencreek, which is more directly polluted than the other sources of supply.

The algae growths in the reservoir supplies often give rise to very offensive tastes and odors, which are in themselves objectionable, and which should be removed. Water charged with such growths may cause diarrhoea or other disturbances in the system of certain people, particularly those not accustomed to the water ; but as far as known, no serious disease is caused by the presence of these organisms in water. The algae are vegetable growths, complex in their nature, and



EXPERIMENTAL TANK

OF

SANITATION CO'S FILTER.

entirely different from the bacteria which cause typhoid fever, cholera and other zymotic diseases. A comprehensive report upon this subject was presented in the annual report of the Reading City Board of Health for the year 1880.

METHODS OF FILTRATION CONSIDERED.

We were particularly instructed by your honorable Board to examine and report upon a method of purification submitted for consideration by the Pennsylvania Sanitation Company, of Philadelphia, Pennsylvania, and which was accompanied by proposals to your honorable Board for the erection of plants for the filtration of the Maidencreek and Antietam supplies, under dates of March 2d and March 15th, 1897.

We have also considered the method commonly known as Slow Sand Filtration, which is extensively used in purifying similar waters in Europe and in this country; and the method of rapid filtration with the use of coagulants, known as Mechanical Filtration, which is extensively employed in the United States.

EXPERIMENTS AND ANALYSES.

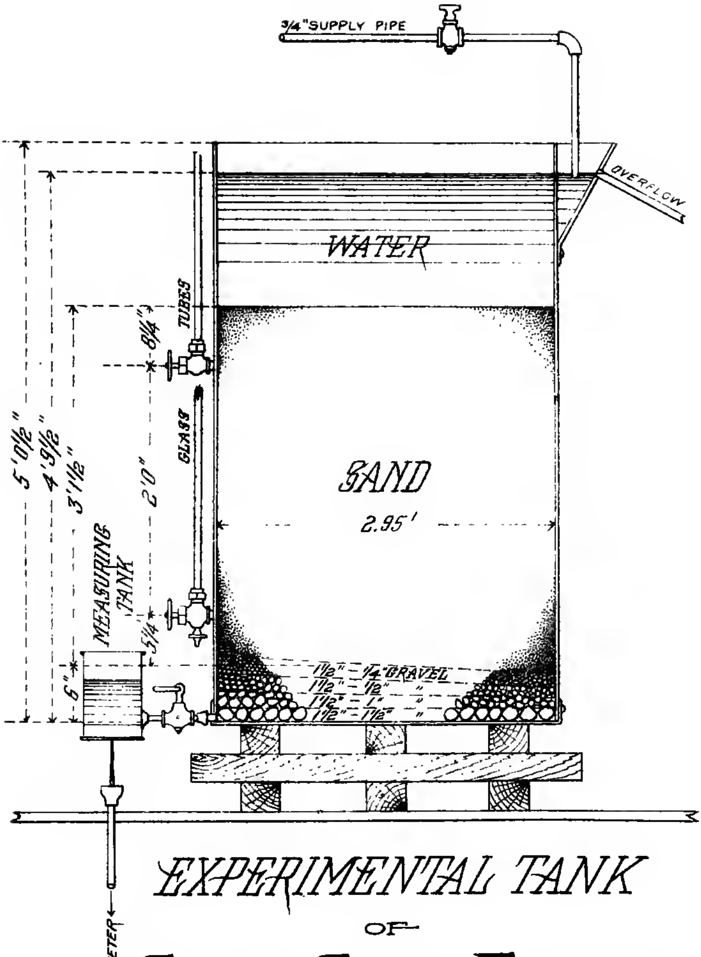
In order to arrive at a better understanding of the principles involved in the method of the Pennsylvania Sanitation Company, and also to determine the results which could be obtained from it in comparison with those obtained from simple filtration, experimental filters were constructed, which were put in operation in April, 1897. The services of Mr. F. S. Hollis, Biologist, formerly and at present in the employ of the City of Boston, were secured to make microscopical and bacterial examinations of the waters applied to, and the effluents from the filters, and also to examine the waters from the various sources of supply of the city. Chemical analyses of the various waters were also made by Mr. H. W. Clark, of the Lawrence Experiment Station of the Massachusetts State Board of Health. The results of these experiments and examinations are given in detail in an appendix to this report.

The filters consisted, briefly, of iron cylinders 2.95 feet in diameter, with areas of 6.835 square feet each. One of these cylinders was provided with a grating made in accordance with the plans of the Pennsylvania Sanitation Company, and upon this grating were placed eight inches of gravel of assorted sizes, ranging from the coarsest gravel at the bottom to fine gravel at the top, and above this, two feet of filter sand having an effective size of 0.24 of a millimeter and a uniformity coefficient of 1.8, which sand is believed to be essentially the same

as that used by the Pennsylvania Sanitation Company in its sewage disposal plant at Reading. Above the sand a device was arranged for distributing water over the surface according to the design of the Pennsylvania Sanitation Co. and an apparatus constructed for delivering water to the same at exactly the determined rate, which rate was in proportion to the quantity of water proposed to be filtered by the said Company in the above mentioned proposals. The effluent dropped from this grating in a manner peculiar to the plans of the Pennsylvania Sanitation Company, and was collected in a galvanized iron tank ten feet below, and overflowed from the same through a meter, which recorded the quantity of water filtered. The filter and appurtenances were in all respects constructed and operated as closely as possible in accordance with the designs submitted to your honorable Board by the Pennsylvania Sanitation Company. The filter was located in one of the buildings of the Water Department; but as special precautions were taken to protect it from dust and other impurities which might not occur in open air, and as the windows were kept open, it is not believed that its location affected in any substantial manner the results obtained.

The second filter was provided with a water tight bottom, and the effluent was collected and taken through a device for indicating the rate of filtration, and afterwards through a meter which recorded the whole quantity of water filtered. Upon the bottom of the tank were placed six inches of assorted sizes of gravel, and four feet of sand above. The sand and gravel were exactly like those used in the other filter. An excess of water was supplied to a small cup on the side of the filter, the excess overflowing, and as much as was required passing through a small hole to the filter, maintaining a constant level. The rate of filtration was regulated entirely at the outlet. This filter was operated continuously, and except at times of scraping, there was no chance for the admission of air to the filtering material, except the air carried in solution by the applied water.

Water was applied to both filters from the mains, and for about a month the water thus supplied was drawn from the Antietam reservoir. Afterward the mains were changed so that the applied water was from Maidencreek. The water from Maidencreek, however, was first pumped into the Hampden reservoir, and thence passed through the pipes to the filters, and the water as applied to the filters differed materially from the water pumped from the creek, owing to the sedimentation and other changes occurring in the reservoir and pipes.



EXPERIMENTAL TANK
OF
SLOW SAND FILTRATION.

The filter constructed on the plans of the Pennsylvania Sanitation Company was operated at a nominal rate of 12,-500,000 gallons per acre daily; but owing to imperfections in the measuring apparatus, the refusal of the filter to take the full quantity of water at times, and other causes, the average yield of the filter when in actual operation was 11,500,000 gallons per acre daily, and taking into account the times when it was out of use for the purpose of being cleaned, the yield was somewhat less. The sand filter was operated at a nominal rate at first of 3,500,000 gallons and afterwards at 4,000,000 gallons per acre daily, but the actual rate was slightly greater, averaging 4.03 million gallons per acre daily for the time it was in actual ooeration

The water supplied to these filters contained at times some of the organisms giving rise to the disagreeable tastes and odors, and itself had such tastes and odors. The effluents from both filters were substantially free from both the organisms and the odors, and were thus satifactory in this respect.*

The water applied to the filters was not at any time seriously discolored by mud, and the filters were not thus subject to as severe tests in this respect as would occur in practice. The numbers of bacteria also were not excessive, and further, the period covered by the experiments was not long enough to allow the best bacterial results to be secured. It seldom happens that a new filter gets into condition to give its highest bacterial efficiency in a shorter period than two or three months, while the whole period covered by the daily bacterial examinations of these filters was less than two months from the time when they were first put into operation. The results in this respect are not as conclusive as could be desired.

A special experiment was carried out on June 1st, when a culture of a special kind of bacteria was mixed with the water applied to each of the filters. This kind of bacteria, called Bacillus Prodigeosus, is red in color, and can be readily distinguished and counted; and as it has been found that it is removed by filtration in substantially the same proportion and under the same circumstances as ordinary sewage bacteria, and as it does not occur in the water or effluent except as applied and as actually passing through the filter, it forms a ready means of showing the bacterial efficiency of filters. At the time of the test both filters had been running several weeks and were in relatively good condition. The number of germs of this species added amounted to 14,000 per cubic centimeter

*See Appendix "A."

of applied water for a period of nine hours. In the effluent from the sand filter a single colony of Bacillus Prodigeosus was found in one sample only. In the effluent from the filter constructed on the plans of the Pennsylvania Sanitation Company, colonies were found in all but one of eleven samples taken within twenty-four hours after its application, the aggregate number of colonies found being 58.

DESCRIPTION OF PROJECTS AND ESTIMATES OF COST.

We have prepared outline plans and estimates of cost of filtration plants for filtering the different supplies by the above mentioned systems. In some respects these projects have not been very fully worked up, and if adopted would probably require to be modified somewhat before being put in final form. For the present we have only aimed to assure ourselves of the practicability of the various schemes, and to secure sufficient data to allow reasonably close estimates of the cost to be made.

SAND FILTERS: *Maidencreek.*—Two projects have been considered. One provides for the construction of filters upon ground somewhat higher than the pumping station, to which water would be pumped and afterwards returned to the present pumping engines, which would pump it as at present. The project provides for 144,000 square feet of effective filtering area, and for open filters, with filter sand four feet in depth, and for devices for regulating the rate of flow, etc., necessary to give the best results. A clear water reservoir is also provided to allow the pumps to be operated steadily and without trouble. The cost of filters by this project, including additional pumping machinery, land damages, connections, and all incidental expenses connected therewith, is estimated at $140,500.

The alternate scheme provides for placing the filters at so low an elevation that they can be flooded from the creek by gravity, and protected against floods by high embankments. This project avoids the second pumping, and no additions would be required to your present pump house. The estimated cost of construction is, however, materially greater, and including connections, land damages, and all incidental expenses, amounts to $186,000. This total is less exact than could be desired, owing to uncertainty as to the amount of rock excavation to be encountered, and further and more detailed examinations by surveys and borings should be made of the proposed site if this project is seriously considered. This project has the advantage of taking the water from Maidencreek above Willow Creek, where the water is softer and otherwise of better quality.

SAND FILTERS: *Antietam.* — This project provides for the construction of three filters having a combined effective filtering area of 45,738 square feet. The filters are placed in such a position that they can be flooded by gravity from the present reservoir, but it will be necessary to draw the effluent out at a lower elevation than the present hydraulic grade of the line. This would naturally result in decreased water pressure in the city. To compensate for this loss of head, provision is made for a new 24-inch pipe line from the filters to Nineteenth street and Perkiomen Avenue. The present pipe line for a part of the distance is only 16 inches in diameter and is badly tuberculated. The friction of the water and the loss of head in the proposed line will be very much less than the friction in the present line, the difference being fully equal to the head lost at the filters, so that the water will be delivered in the city at fully as great a pressure as at present when the pipe is carrying 3,500,000 gallons per day.

The estimated cost of these filters, including a new pipe line, land damages, and all incidental expenses connected therewith, is $50,500.

SAND FILTERS: *Bernhart.*—The project for the filtration of the Bernhart water is very similar to that proposed for the Antietam. Three filters are contemplated with a combined effective filtering area of 32,670 square feet. The filters would be located below the reservoir and water would flow to them from it. To maintain the pressure in the water mains, an additional line of 20-inch pipe is provided, which will take the water from the outlet of the filters and deliver it to the city at somewhat greater pressure than will the present smaller lines taking water from the reservoir direct, and when delivering at a rate of 2,500,000 gallons of water daily. The estimated cost of filters by this project, including the new pipe line, land damages, connections and all expenses incidental thereto, is $44,900.

An alternate project has been suggested for the filtration of this supply, which would involve pumping the water to filters at a greater elevation, from which it would flow through the present pipe lines to the city.

This project would give a somewhat better pressure and the first cost would be a little less, but the operating expenses of an additional pumping station would very much more than offset the saving in first cost, and this project has not been further considered.

SAND FILTERS: *Egelman.*—This plan provides for the construction of two filters with a combined effective filtering area

of 4,360 square feet, immediately below the reservoir, the outlet of the filters being connected with the present supply main. An automatic device would control the height of water on the filters, drawing water from the reservoir as required. This plant would be extremely simple in its construction and operation. As the present watchman could take all necessary care of the filters, the only expense for the operation would be replacing a small quantity of sand each year. The cost of the filters, including land damages, etc., is estimated at $6,900.

PENNSYLVANIA SANITATION COMPANY'S PROJECT: *Maidencreek.*—The basis of this estimate is a proposal submitted by the Pennsylvania Sanitation Company to your honorable Board, under date of March 2, 1897. The project provides for the location of filters over the Hampden reservoir on an elevated steel structure. The water would be pumped to these filters, and would fall from them into the reservoir. As the above mentioned proposition provides for the construction of a plant smaller than we deem advisable for this supply, we have increased the number of sections of filters from six to ten and have increased the price in the same ratio. The ten beds have an effective filtering area of 35,112 square feet. At present the Maidencreek water is pumped to the Hampden reservoir, but in the plans adopted for the developments of the city supply, it is the intention to pump a part of this water directly into the distribution system without first going to the reservoir. We have therefore included in our estimate such additional piping as will be necessary with the increased supply to carry the whole of the Maidencreek water to the Hampden reservoir. We have not taken up the question as to whether or not there will be damages to the reservoir by the location of such filters over it, nor the question as to whether or not suitable provisions have been made for foundations, nor whether the structures proposed were in all respects strong and substantial enough for the purposes intended. The cost of the filters, as given in the above mentioned proposal, amounts to $3.42 per square foot of effective filtering area, or $120,000 for the area provided, and with the additional piping required, and all other expenses incidental thereto, is estimated at $189,500.

PENNSYLVANIA SANITATION COMPANY'S PROJECT: *Antietam Supply.*—The basis of this estimate is a proposal made by the Pennsylvania Sanitation Company, under date of March 15, 1897. The filters are to be located upon an elevated steel structure immediately below the Antietam dam, and to have an effective filtering area of 14,045 square feet. As the effluent would be delivered at a much lower level than the present

hydraulic grade in the pipe, it would be necessary in order to maintain the same pressure to lay additional pipe to decrease the friction. In the project for sand filters this reduction of friction is effected in the lower part of the line where the fall is rapid and the present pipe line smaller. In this case this is impracticable, as the pipe line below the filters for a long distance has a very flat grade, and increasing the size of the pipe at the lower end of the line would not increase the delivery or pressure, which would be limited by the possible discharge through the flat section of pipe under the head available at its upper end. The only way to secure the necessary discharge and pressure, is to lay an additional line and thus still further reduce the friction in the flat part of the line. The cost of the filters as stated in the above mentioned proposal, is $49,000, or $3.49 per square foot, and with the additional pipe and connections, land damages, and all incidental expenses, is estimated at $79,200.

PENNSYLVANIA SANITATION COMPANY'S METHOD: *Bernhart and Egelman.*—No estimates have been made of the cost of filtering these supplies by this method, as the difficulties existing at Antietam exist in even greater measure in connection with these supplies. The cost of the Pennsylvania Sanitation Company's project for the Antietam supply is considerably greater than that of either sand or mechanical filtration, and, as will be developed below, there is no reason for preferring it. Since it is obvious that the conditions at Bernhart and Egelman would not be in any respect more favorable for the installation of this system, we have not thought it necessary to make estimates for it.

MECHANICAL FILTERS: *Maidencreek.*—This project provides for the construction of thirty-two 12-foot mechanical filters, or their equivalent in filters in other diameters, having a combined effective filtering area of 3,680 sq. ft. Water would be pumped from the present pump well to the filters, and from the filters would drain to a pure water reservoir, from which it would be pumped by the present pumps and through the present mains. A suitable house is required for covering the filters, and new pumps, boilers, &c., will be required. The total cost of filters, including connections, pumps, house, land damages, and all expenses incidental thereto, is estimated at $128,000.

MECHANICAL FILTERS: *Antietam.*—The location of mechanical filters for the Antietam supply would depend upon the type of filters employed. Mechanical filters can be constructed to be operated with as little loss of head as sand filters, and if such a type of mechanical filter should be employed, filters

could be located at the sites selected for sand filters, and the cost of a mechanical filtration plant, having a combined effective filtering area of 1,380 square feet, with power for stirring, pumps for wash-water, changes in piping and connections, house, small clear water well, land damages and all incidental expenses, is estimated at $41,700.

If, on the other hand, mechanical filters should be used, requiring a greater loss of head, such as most of the filters now in use require, a much greater change in the piping system would be required, and the cost would be considerably increased.

MECHANICAL FILTERS: *Bernhart.*—The project provides for nine 12-foot filters, having a combined effective filtering area of 1,030 square feet, located below the reservoir. In case filters should be used having only a slight loss of head, the effluent would not require to be pumped, but the pipe line would require to be increased in size in the same way as mentioned in connection with the sand filter plant for Bernhart. A small boiler and pump would be required for pumping wash-water and power for stirring, also a small pure water reservoir. The total cost, including land damages, is estimated at $44,000. If mechanical filters of the ordinary type, requiring a greater loss of head, should be employed, and the pipe line should be left as at present, and a pumping plant installed to pump the effluent into the mains, the estimated cost, including land damages and all incidental expenses, is $35,500, but the operating expenses in this case would be considerably greater.

MECHANICAL FILTERS: *Egelman.*—This project includes two mechanical filters with a combined effective filtering area of 226 square feet, placed below the reservoir and discharging their effluent directly into the main, with a suitable house, a small boiler, engine, and pump for wash-water and stirring. The total cost of this plant is estimated at $8,300.

OPERATING EXPENSES.

In estimating the operating expenses, it has been assumed that the quantity of water from Maidencreek for some years to come will average 1,000 million gallons per annum; that 1,050 million gallons will be used from the Antietam reservoir; 650 million gallons from the Bernhart reservoir, and 75 million gallons from the Egelman reservoir. The care of sand filters has been estimated at $2.50 per million gallons of water filtered, which seems an ample allowance in view of the comparative clearness of your waters and the long periods which will occur between scrapings, tending to low operating expenses.

The care of the Pennsylvania Sanitation Company's filters has been estimated at the same figure, it having been found by calculations from our experiments that the area of filter surface to be cleaned in the course of a year would be slightly greater for the Pennsylvania Sanitation Company's apparatus than for sand filters, the cost of cleaning per unit of area being substantially the same. The rate of filtration was three times as great with the Pennsylvania Sanitation Company's filter, but the filter required to be scraped three to four times as often. No allowance has been made for painting and other care of the steel.

In mechanical filters one-half a grain of alum to the gallon has been allowed for the filtration of the reservoir supplies, and one grain to the gallon for the Maidencreek supply. Estimates have been made in each case of the additional cost of pumping where required, and of the wages of the men required for the operation of the mechanical filters, and of the wash-water required, which has been estimated at ten dollars per million gallons. In the case of the Maidencreek supply this may be taken as representing the actual cost of the water at the works pumped and filtered, but is probably less than the actual costs for the reservoir supplies. The operating expenses estimated in this way are included below in the tabular summary of estimates.

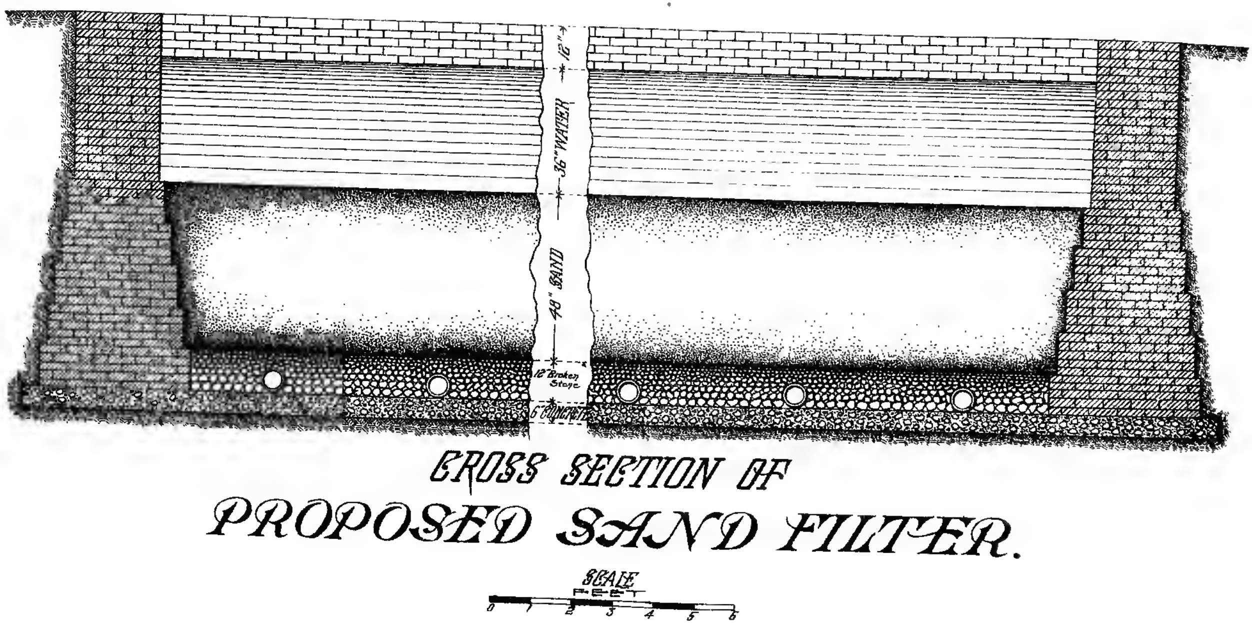
SUMMARY OF ESTIMATES.

Below is given a summary of the areas and capacities of the various proposed filters mentioned above, and their estimated costs, and the charges for interest and sinking funds, reckoned thereon at five per cent., and also the operating expenses when filtering the annual quantities of water mentioned, and the sum of the operating expenses and five per cent. of the first costs, which sums taken together represent approximately what the annual costs would be to the city for the filtration of the water by the various plans.

	Area of filters; square feet.	Capacity of filters; million gals. per day.	Estimated quantity of water to be filtered per annum; million gallons.	Cost of construction.	5 per cent. of cost of construction.	Operating expenses.	Operating expenses and 5 per cent. of construction
Maidencreek. — Sand filters by gravity.........	144,000	9.0	1,000	$186,000	$9,300	$2,500	$11,800
Maidencreek. — Sand filters by pumping........	144,000	9.0	1,000	140,500	7,025	3,750	10,775
Antietam.--Sand filters	45,738	3.5	1,050	50,500	2,525	2,625	5,150
Bernhart.--Sand filters...........	32,670	2.5	650	44,900	2,245	1,625	3,870
Egelman. -Sand filters	4,360	0.5	75	6,900	345	225	570
Maidencreek. Penna. San. Co.'s method..	35,112	9.0	1,000	189,500	9,475	2,720	12,195
Antietam. — Penna. San. Co.'s method..	14,045	3.5	1,050	79,200	3,960	2,625	6,585
Maidencreek. — Mechan. filters	3,680	9.0	1,000	128,000	6,400	4,784	11,184
Antietam. —Mechan. filters...	1,380	3.5	1,050	41,700	2,085	4,750	6,835
Bernhart. — Mechan. filters, pumping...	1,030	2.5	650	35,500	1,775	4,156	5,931
Bernhart. — Mechan. filters, gravity..........	1,030	2.5	650	44,000	2,200	3,656	5,856
Egelman.— Mechan. filters...	226	0.5	75	8,300	415	1,317	1,732

PRINCIPLES OF PURIFICATION INVOLVED IN THE DIFFERENT METHODS.

Sand Filtration.—The sand filters in the above mentioned estimates are the sand filters commonly employed in Europe and in this country, provided with most approved regulating appliances. The general form and construction of these filters is shown by the accompanying drawing. They consist of open basins with water-tight bottoms surrounded by masonry walls. Underdrains are placed at the bottom, surrounded by gravel and over the gravel four feet of filter sand are placed. The water is taken over the surface of the sand and filters down-



CROSS SECTION OF
PROPOSED SAND FILTER.

ward through the sand, is collected by gravel and underdrains and passes out purified. The area provided is such that at times of greatest consumption the rate of filtration of the reservoir supplies will never exceed 5,000,000 gallons per acre daily with one filter out of use, and for the Maidencreek supply the highest rate will be 3,000,000 gallons per acre daily with reserve for cleaning.

The processes resulting in the purification of the water in passing the sand are very complex and need not be discussed in detail here. They consist in part of the straining out ot the suspended matters and in part of the oxidation of suspended or dissolved organic matters, this oxidation being carried out by the oxygen dissolved in the water applied. It is thus important that the water applied to the filters should be aerated, and devices are included in the estimates for aerating the water as it enters the filters. The system of sand filtration can be depended upon at all times to remove the muddiness in the waters, and the organic matters producing tastes and odors and the odors themselves, and should there be any objectionable bacteria in the applied water, the filters can be depended upon to remove substantially all of them.

Pennsylvania Sanitation Company's Process.—The filters of the Pennsylvania Sanitation Company are constructed under certain patents. The peculiarity of this system consists in the use of elevated filters supported on steel structures. The sand is supported by a thin layer of gravel which in turn rests upon an open grating, and there is no system of underdrainage, but the effluent from every part of the filter drops at once from the grating into a receptacle or reservoir below. The depth of sand employed is two feet, or only half as great a depth as is used in sand filtration.

The prices in the proposals submitted to your honorable Board amount to about $3.40 per square foot of filtering area. We have taken these bids as a basis of estimates and have not taken up the question as to whether the prices were reasonable ones for the construction of the apparatus in question, as the apparatus is covered by patents, and the Pennsylvania Sanitation Company can undoubtedly make such prices as it sees fit on that part of the apparatus covered by patents and not open to competition.

The cost is about four times as much per square foot as the cost of sand filters, and in order to bring the system as a whole into the same range of cost as other systems of filtration, or for reasons not known to us, the Pennsylvania Sanitation Company recommend that it be used at a rate of filtration of 12,500,000 gallons per acre daily.

The rate of filtration which can be safely employed in sand filtration is the outcome of the experience of sixty years, and of hundreds of cities. The rates of filtration mentioned in connection with sand filtration are considered perfectly safe. It is well known that under favorable conditions rates of filtration can be employed considerably greater than those considered in our estimates for sand filters. There is, however, an element of danger in the use of higher rates, and the proportion of bacteria which passes a filter, increases very rapidly as the rate increases. In our experiments, and particularly in the experiments with bacillus prodigeosus, the proportion of that kind of bacteria which passed the filter constructed on the plans of the Pennsylvania Sanitation Company, was much larger than the proportion passing the sand filter ; and we believe that one of the most important elements in this difference was the higher rate, and also the less depth of sand, and we do not consider the depth of sand sufficient, and the rate of filtration low enough in the plant of the Pennsylvania Sanitation Company, to insure the removal of objectionable bacteria, should such be present in the applied water.

It has been suggested that the aeration of the filtering material and of the effluent in this system play an important part in the purification. The effluent is certainly most thoroughly aerated as it falls from the filter, and if it contained objectionable odors from dissolved gases, this aeration would tend to evaporate and remove the same. The aeration will not, however, remove any turbidity or muddiness resulting from too high a rate of filtration or too shallow a sand bed, nor will it remove any objectionable bacteria which may have passed the filter, for similar reasons. The alleged removal or destruction of bacteria by electrification due to the impact of the falling drops of water on the surface of the water below has not made itself apparent in our experiments, and we have not been able to discover the slightest reason for supposing that any bacterial purification is effected in this way.

This system of filtration is also lacking in one respect most essential to securing the best results by any system of filtration, namely, the regulation.

The bottom being open at every point, the effluent is free to pass away as fast as it can get through the sand, and the only possible regulation consists in applying the water at a constant rate and distributing it over the whole area of the sand. A perfect distribution of water over a large filtering surface, that surface being open enough to carry off all the water it receives, has not yet been achieved.

The plans shown by the Pennsylvania Sanitation Company show the water applied at a large number of points, but there is no attempt made to distribute the applied water to every point in the filters. When the sand is cleaned, water is applied to it at various points and runs through the sand at these points. With a head equal to the depth of sand, as it practically is in this case, before the water starts to accumulate on the surface, and counting the water column in the sand itself, which is equal to the height of the sand, water will flow through sand of the coarseness used in these filters at about five times the rate recommended for the operation of the plant. That is to say, if the nominal quantity of water is applied to a given section, the sand being clean, it will run through about one-fifth of that section at about five times the nominal rate, the other four-fifths of the section remaining out of use.

As the sand in that part of the filtering area first brought into use becomes somewhat clogged by the suspended matters in the applied water, the rate of filtration in this section is reduced, the water on the surface extends farther, and other parts of the filtering area are brought into action which filter at first at the same rate, that is, at five times the nominal rate. This clogging and moving of the center of action gradually goes on until the water extends over the whole surface of the filter. When the water has covered the whole surface it gradually increases in depth and the head is thus increased, overcoming the increased friction. This goes on until the water is a foot deep, and the head amounts to one and a half times the depth of sand. The filter must then be allowed to drain off and be cleaned, otherwise the applied water would overflow.

It is obvious that this procedure is not calculated to give a high bacterial efficiency, and that this system of filtration cannot be depended upon to remove objectionable bacteria, should such be found in the raw water, and for this reason it is not suitable for the Maidencreek supply. The filtration removes nearly all of the organisms causing disagreeable tastes and odors and the odors themselves, and would thus, if applied, remove one of the most serious objections to your reservoir supplies. An inspection of the table of estimates, however, shows that this system is more expensive than either sand or mechanical filtration for the Antietam supply, and we have reason to think that it would also be more expensive for the Bernhart and Egelman supplies.

As between sand filtration and the Pennsylvania Sanitation Company's filtration, the latter substitutes a smaller area of much more expensive filtering surface, and is open to the dis-

advantages of requiring a much higher rate of filtration, which is objectionable; to that of using a less depth of sand, which is also objectionable; to the entire absence of adequate regulation, which is very objectionable; and to numerous structural defects which we deem it unnecessary to take up at the present time in detail. Its advantage consists in the very thorough aeration of the effluent, but this aeration is often unnecessary, and if at any time required, can be much more cheaply provided in another way.

Mechanical Filters.—The subject of mechanical filtration is in several respects in unsatisfactory shape. The essential feature of mechanical filtration consists in the use of a rate of filtration forty or fifty times as great as is employed in sand filtration, and in the use of sulphate of alumina or alum. The function of alum is to coagulate and draw together the very fine suspended matters of the water and allow them to be more readily removed, and so to allow rates of filtration to be employed which would otherwise be quite impossible. The successful purification of water with very high rates of filtration is absolutely dependent upon the use of alum or other coagulants. The Hyatt patent covering the use of alum applied as it would necessarily be applied with your conditions does not expire until 1901, and prior to that time there is a question as to your right to use mechanical filtration unless the filters are secured from the owners of the above mentioned patent. Our estimates for mechanical filters are for plants constructed in accordance with the principles which we believe best adapted to secure good results by this system of purification.

Whether or not you would be able to secure the use of such filters prior to the expiration of the above mentioned patent, is a question which we are unable to determine, but which must be settled before this system of filtration is adopted.

Mechanical filtration for the reservoir supplies is open to the objection that small pumping or power plants would be required for pumping wash-water and stirring the filtering material, necessitating keeping up steam and the cost of constant attendance. These features are avoided by sand filters, which can be made largely automatic in their action and which require no steam or power plants for their operation. With the reservoir supplies the difference in operating expenses is an important reason for not adopting mechanical filters. For the Maidencreek supply this objection is less important, as all of the machinery could be concentrated in the immediate neighborhood of your present pumping station, and the present staff, with such increase as might be necessary, would attend to its

operation. In this case mechanical filters, all question of patent rights aside, would be $12,500 cheaper than sand filters on a corresponding site and with corresponding pumping machinery. The cost of operating expenses is about $1,000 greater, owing to the alum required. Taking into account the interest on the cost of construction and the operating expenses, the difference in cost between sand and mechanical filtration is not important, and we prefer the one which we consider the most certain to yield at all times a thoroughly purified effluent, and the one which avoids all possible discussion or litigation in regard to patent rights, namely, Sand Filtration.

CONCLUSIONS.

We find that the waters of the different supplies are subject to various sources of pollution, and are, or may become, at some time, injurious to health. All of them are sometimes muddy, and three of them are subject to disagreeable tastes and odors. We find that these unhealthy and disagreeable qualities can be removed by suitable filtration, and we consider it for the best interests of the City of Reading that they should be so removed. We find that the system of filtration of the Pennsylvania Sanitation Company is very expensive per unit of filtering area as compared with sand filtration, and that it has no corresponding advantages, while it is open to very serious and fundamental objection, and in the case of the Maidencreek supply, at least, is unsuitable for the work to be done. We find that mechanical filtration properly carried out with filters of the best type will not be very much cheaper than sand filtration, while the operating expenses will be considerably greater. We do not consider that it will give in any respect better results than those obtained from sand filtration. It is not even certain that as good results can be obtained from it, while there may be difficulty in getting filters of the best type while avoiding litigation in regard to patent rights.

We respectfully recommend the construction of sand filters as being the best adapted to the requirements of the City of Reading.

Respectfully submitted,

EMIL L. NUEBLING,
Superintendent and Engineer of Water Works.

ALLEN HAZEN,
Consulting Engineer.

December 30, 1897

APPENDIX "A."

FILTRATION EXPERIMENTS.

CHEMICAL ANALYSES
—OF—
APPLIED WATER AND EFFLUENTS.

BY H. W. CLARK.

DATE OF COLLECTION, APRIL 24, 1897; OF EXAMINATION, APRIL 28, 1897.

Samples correspond with Biological samples Nos........	9	10	11	12
	IN PARTS PER 100,000.			
	Applied Water "Antietam"	Effluent Sand Tank.	Effluent Sanit'n Co.'s Bed.	Effluent Sanit'n Co.'s Pan.
Turbidity..............	none.	very slight.	very slight.	very slight.
Sediment..............	very slight.	very slight.	very slight.	very slight.
Color....................	0.23	0.22	0.21	0.21
Odor....................	none.	very slight.	none.	very slight.
Total Solids (in 100,000)............	7.70	6.80	7.80	8.70
Hardness..............	2.40	2.60	2.40	2.40
Chlorine...............	0.12	0.12	0.14	0.11
Free Ammonia........	0.0028	0.0038	0.0132	0.0790
Albuminoid Am'nia	0.0144	0.0122	0.0146	0.0142
Nitrogen as Nitrates	0.0500	0.0640	0.0620	0.0620
Nitrogen as Nitrites	0.0000	0.0000	0.0004	0.0002
Oxygen consumed...	0.2500	0.1900	0.2000	0.2500

BIOLOGICAL EXAMINATIONS OF WATER APPLIED TO FILTERS, AND OF EFFLUENTS.

By F. S. HOLLIS.

Number of Organisms in Standard Units per Cubic Centimeter.

DATE OF COLLECTION, APRIL 24, 1897.

Numer of Sample.	9	10	11	12
	Applied Water.	Effluent Sand Tank.	Effluent Sanit'n Co.'s Bed.	Effluent Sanit'n Co.'s Pan.
Diatomaceae:				
Asterionella	392			
Cyclotella	20			
Synedra	9	3	2	3.5
Navicula	1	0.5	0.5	
Desmideae:				
Staurastrum	6			
Infusoria:				
Dinobryon cases	6			
Chloromonas	14			
Monas	2			
Cercomonas			2	
Rhizopoda:				
Actinophrys		8.0		
Total	450	11	4	3
Amorphous	336	84	112	98
Odor	vegetable.	none.	very faintly vegetable.	faintly vegetable and aromatic.
Remarks	contains some clay and iron rust	contains some clay and iron rust		contains some clay.
Bacteria per C. C.	394	117	160	1293

BIOLOGICAL EXAMINATIONS, &c.—*Continued.*

DATE OF COLLECTION, APRIL 25, 1897.

Number of Sample.	13	14	15	16
	Applied Water.	Effluent Sand Tank.	Effluent Sanit'n Co.'s Bed.	Effluent Sanit'n Co's. Pan.
Diatomaceae:				
Asterionella.........	336	1.5		
Synedra..............	16	1	3.5	0.5
Melosira..............	6		8	
Cyclotella	13			0.5
Navicula..............	2.5			
Chlorophyceae:				
Protococcus	4		4	2
Desmideae:				
Staurastrum	15			
Infusoria:				
Chloromonas.......	3.5			
Monas	0.5	0.2		
Cercomonas.........	2			
Total	398	3	15	3
Amorphous	108	58	86	78
Odor	vegetable strong oder of asterion'a.	faintly vegetable.	faintly vegetable.	very faintly vegetable.
Remarks................			cont's some iron rust and veget'e fibre.	contains much clay.
Bacteria per C. C.....	300	138	149	1320

BIOLOGICAL EXAMINATIONS, &c.—*Continued.*

DATE OF COLLECTION, APRIL 27, 1897.

Number of Sample.	17	18	19	20
	Applied Water.	Effluent Sand Tank.	Effluent Sanit'n Co.'s Bed.	Effluent Sanit'n Co.'s Pan.
Diatomaceae:				
Cyclotella	10.5		1.5	
Asterionella	131			2.5
Synedra	10	1	1	2
Navicula	3	1	0.5	
Stephanodiscus			2	
Chlorophyceae:				
Pandorina	8			
Protococcus	12			10
Infusoria:				
Chloromonas	5			
Trachelomonas		2		
Cercomonas			4	2
Miscellaneous:				
Insect scale			6	
Total	179	4	15	16
Amorphous	144	36	112	52
Odor	vegetable char'cterist'c odor of asterionella.	none.	very slightly vegetable.	very slightly vegetable.
Remarks	contains considerable clay.			contains much clay.
Bacteria per C. C.	355	60	158	198

BIOLOGICAL EXAMINATIONS, &c.—*Continued.*

DATE OF COLLECTION, APRIL 29, 1897.

Number of Sample.	24	25	26	27
	Applied Water.	Effluent Sand Tank.	Effluent Sanit'n Co.'s Bed.	Effluent Sanit'n Co.'s Pan.
Diatomaceae:				
Synedra	20	0.5		2
Asterionella	220.5		1	1
Cyclotella	6.5			
Navicula	3			0.5
Chlorophyceae:				
Protococcus	26	4	4	
Desmideae:				
Staurastrum	9			
Closterium		1		
Cyanophyceae:				
Oscillaria	16			
Infusoria:				
Chloromonas	7			
Rhizopoda:				
Actinophrys		6	6	
Miscellaneous:				
Crustacean Fragments	20	10		
Total	328	21	11	3
Amorphous	180	50	62	68
Odor	slightly vegetable.	faintly earthy.	faintly vegetable.	faintly vegetable and earthy.
Remarks		contains some iron rust.	contains considerable clay.	contains some clay.
Bacteria per C. C.	416	89	176	280

BIOLOGICAL EXAMINATIONS, &c.—*Continued.*

DATE OF COLLECTION, APRIL, 30, 1897.

Number of Sample.	29	30	31	32
	Applied Water.	Effluent Sand Tank.	Effluent Sanit'n Co.'s Bed.	Effluent Sanit'n Co.'s Pan.
Diatomaceae:				
Navicula	4.5			0.5
Synedra	7.0		2	0.5
Asterionella	210.5		1	0.5
Cyclotella	12.5		0.5	
Cymbella	1			
Chlorophyceae:				
Protococcus	12			
Pandorina	16			
Conferva	20			
Raphidium		1		
Desmideae:				
Staurastrum	18			
Infusoria:				
Chloromonas	10			
Cercomonas	2		1	
Trachelomonas	2			
Codonella	24			
Rotifera:				
Rotifer	40			
Miscellaneous:				
Crustacean frag	16			
Total	395	1	4	1
Amorphous	254	50	62	62
Odor	vegetable odor of asterionella could be detected.	very slightly vegetable.	slightly vegetable.	slightly vegetable.
Remarks		considerable iron rust and some clay.		contains some clay and iron rust
Bacteria per C. C.	460	180	180	175

BIOLOGICAL EXAMINATIONS, &c.—*Continued.*

DATE OF COLLECTION, MAY 1, 1897.

Number of Sample.	33	34	35	36
	Applied Water.	Effluent Sand Tank.	Effluent Sanit'n Co.'s Bed.	Effluent Sanit'n Co.'s Pan.
Diatomaceae:				
Asterionella	203			
Navicula	6.5	0.5	1	
Synedra	11	1		
Cyclotella	16	0.5	1.5	1
Surirella	3			
Chlorophyceae:				
Protococcus	12		4	14
Desmideae:				
Staurastrum	6			
Closterium	6			
Infusoria:				
Chloromonas	10	0.5		2
Euglena	0.5			4
Trachelomonas	1		2	
Rhizopoda:				
Actinophrys	28			
Rotifera:				
Rotifer	68			
Miscellaneous:				
Crustacean frag.	20			10
Total	391	2	8	31
Amorphous	224	46	90	60
Odor	vegetable odor of asterionella.	none.	faintly vegetable.	vegetable and faintly unpleasant.
Remarks	contains some clay and rust.	contains considerable clay.	contains considera'e clay & veget. fibre	contains considerable clay.
Bacteria per C. C.	486	145	135	272

BIOLOGICAL EXAMINATIONS, &c.—*Continued.*

DATE OF COLLECTION, MAY 3, 1897.

Number of Sample.	37	38	39	40
	Applied Water.	Effluent Sand Tank.	Effluent Sanit'n Co.'s Bed.	Effluent Sanit'n Co.'s Pan.
Diatomaceae :				
Asterionella.........	21.5			
Navicula............	10			
Synedra.............	22			
Cyclotella..........	8.5		2.5	1
Cymbella............	1			
Pleurosigma........			2	
Chlorophyceae :				
Protococcus.........	20	4	4	
Desmideae :				
Staurastrum........	12			
Fungi :				
Mould................			122	10
Infusoria :				
Chloromonas.......	8			2
Peridinium	6			
Cercomonas.........			2	
Rotifera :				
Rotifer...............	190			24
Miscellaneous :				
Spores..........			12	4
Total...............	299	4	144	41
Amorphous............	188	50	64	52
Odor	vegetable and earthy.	faintly vegetable.	slightly vegetable and unpleasant.	slightly vegetable.
Remarks	contains much clay.		contains considerable clay.	contains some clay and rust.
Bacteria per C. C....	1680	105	260	390

BIOLOGICAL EXAMINATIONS, &c.—*Continued.*

DATE OF COLLECTION, MAY 6, 1897.

Number of Sample.	41	42	43	44
	Applied Water.	Effluent Sand Tank.	Effluent Sanit'n Co.'s Bed.	Effluent Sanit'n Co.'s Pan.
Diatomaceae:				
Asterionella.........	9.5	1	1	2
Navicula.............	4			
Cyclotella...........	5.5	1.5	1.5	2
Synedra..............	10			
Chlorophyceae:				
Pandorina...........	12			
Pediastrum.........	6			
Protococcus........	16			
Desmideae:				
Staurastrum........	12			
Fungi:				
Mould....			30	
Infusoria.				
Chloromonas.......	3			1
Trachelomonas....				4
Miscellaneous:				
Crustacean frag...		6		
Total.........	78	8	32	9
Amorphous............	140	42	68	62
Odor......................	vegetable.	faintly earthy.	faintly vegetable.	faintly vegetable.
Remarks.........				contains considerable rust.
Bacteria per C. C., May 4................	1518	82	180	270
Bacteria per C. C., May 6................	650	117	206	280

BIOLOGICAL EXAMINATIONS, &c.—*Continued.*

DATE OF COLLECTION, MAY 10, 1897.

Number of Sample.	49	50	51	52
	Applied Water.	Effluent Sand Tank.	Effluent Sanit'n Co.'s Bed.	Effluent Sanit'n Co.'s Pan.
Diatomaceae :				
Synedra	13	1		1.5
Cyclotella	1		0.5	
Asterionella	13.5		2	3
Navicula	3.5		1.5	
Cymbella	1			
Melosira	26			
Chlorophyceae :				
Pandorina	128			
Protococcus	22	4	6	4
Fungi :				
Mould		20	5	10
Infusoria :				
Chloromonas	5			1
Trachelomonas	6		2	
Cryptomonas		2		
Rotifera :				
Rotifer	24	16		
Anuraea	16			
Total	259	43	17	19
Amorphous	134	44	54	54
Odor	vegetable and slightly unpleasant.	faintly vegetable and earthy.	faintly earthy and vegetable.	slightly vegetable and earthy.
Remarks			contains much clay.	contains much clay.
Bacteria per C. C., May 7	480		94	140
Bacteria per C. C., May 8	480	130	115	133
Bacteria per C. C., May 10	520	113	190	210

BIOLOGICAL EXAMINATIONS, &c.—*Continued.*

DATE OF COLLECTION, MAY 13, 1897.

Number of Sample.	59	60	61	62
	Applied Water.	Effluent Sand Tank.	Effluent Sanit'n Co.'s Bed.	Effluent Sanit'n Co.'s Pan.
Diatomaceae :				
Asterionella	17.5			1
Navicula	1.5		2	2
Synedra	22.5	1.5		1
Cymbella	1			
Cyclotella	5.5		1	
Chlorophyceae :				
Pandorina	272.0			
Raphidium	8			
Protococcus	6	12		
Cyanophycea :				
Microcystis	12			
Fungi :				
Mould			20	
Infusoria :				
Chloromonas	2	1		1
Trachelomonas	4			
Cercomonas			4	
Monas			0.5	
Rotifera :				
Rotifer	20			
Anuraea	24			
Total	396	14	27	5
Amorphous	146	40	60	56
Odor	vegetable.	faintly vegetable and earthy.	very slightly vegetable.	slightly vegetable and unpleasant.
Remarks	contains considerable clay.	contains considerable clay and rust	contains much clay.	
Bacteria per C. C., May 11	676	127	166	225
Bacteria per C. C., May 12	590	160	180	290
Bacteria per C. C., May 13	730	130	179	320

BIOLOGICAL EXAMINATIONS, &c.—*Continued.*

DATE OF COLLECTION, MAY 17, 1897.

Number of Sample.	63	64	65	66
	Applied Water.	Effluent Sand Tank.	Effluent Sanit'n Co.'s Bed.	Effluent Sanit'n Co.'s Pan.
Diatomaceae:				
Synedra	60.5	1	1	1
Asterionella	34.5			
Fragilaria	15			
Navicula	0.5	1		1
Cyclotella	1		1	0.5
Cymbella	1			
Chlorophyceae:				
Pandorina	24			
Fungi:				
Mould			10	
Infusoria:				
Monas	0.5			
Cercomonas	2			
Chloromonas			1	
Cryptomonas		4		
Rotifera:				
Rotifer	44			20
Anuraea	48			
Total	231	6	13	22
Amorphous	134	36	58	48
Odor	slightly vegetable.	slightly earthy.	faintly vegetable and earthy.	faintly vegetable.
Remarks	contains clay and iron rust.			
Bacteria per C. C., May 14	·980	162	215	385
Bacteria per C. C., May 15	995	160	134	270
Bacteria per C. C., May 16	198	95	120	210
Bacteria per C. C., May 17	154	40	42	105

BIOLOGICAL EXAMINATIONS, &c.—*Continued.*

DATE OF COLLECTION, MAY 21, 1897.

Number of Sample.	75	76	77	78
	Applied Water.	Effluent Sand Tank.	Effluent Sanit'n Co.'s Bed.	Effluent Sanit'n Co.'s Pan.
Diatomaceae :				
Asterionella	13			1
Synedra	57	0.5		0.5
Cyclotella	5	0.5		
Navicula	1			
Chlorophyceae :				
Scenedesmus	5.3			
Protococcus	12			
Cyanophyceae :				
Oscillaria	8			
Fungi :				
Mould			10	
Infusoria :				
Chloromonas	2	1	1	
Mallomonas	2			
Miscellaneous :				
Pine pollen			8	
Total	105	2	19	1
Amorphous	134	38	48	46
Odor	none.	none.	very faintly vegetable.	slightly vegetable.
Remarks	contains some clay.	contains some clay.		
Bacteria per C. C., May 18	203	42	38	86
Bacteria per C. C., May 19	232	45	170	320
Bacteria per C. C., May 20	132	32	62	150
Bacteria per C. C., May 21	142	40	42	200

BIOLOGICAL EXAMINATIONS, &c.—*Continued.*

DATE OF COLLECTION, MAY 24, 1897.

Number of Sample.	79	80	81	82
	Applied Water.	Effluent Sand Tank.	Effluent Sanit'n Co.'s Bed.	Effluent Sanit'n Co.'s Pan.
Diatomaceae :				
Synedra	25.5	1	1	3
Asterionella	2.5			
Navicula			2	0.5
Chlorophyceae :				
Pandorina	12			
Protococcus	6	4		
Desmideae :				
Staurastrum	6			
Fungi :				
Mould			2	10
Infusoria :				
Chloromonas	1			
Monas			0.2	
Total	53	5	5	13
Amorphous	102	34	52	46
Odor	faintly earthy.	none.	none.	none.
Remarks	very clear.	contains a little clay.		contains a little clay.
Bacteria per C. C., May 22	200	15	14	150
Bacteria per C. C., May 23	140	25	lost.	233
Bacteria per C. C., May 24	93	26	27	275

BIOLOGICAL EXAMINATIONS, &c.—*Continued.*

DATE OF COLLECTION, MAY 27, 1897.

Number of Sample.	88	89	90	91
	Applied Water.	Effluent Sand Tank.	Effluent Sanit'n Co.'s Bed.	Effluent Sanit'n Co.'s Pan.
Dialomaceae :				
Synedra	39	0.75	1.25	1
Cyclotella	2			
Asterionella	1.5			
Navicula	6			
Chlorophyceae :				
Protococcus	6			
Raphidium			0.5	
Cyanophyceae :				
Oscillaria		8		
Miscellaneous :				
Grain pollen				6
Total	54	9	2	7
Amorphous	124	40	60	52
Odor	slightly vegetable and earthy.	faintly earthy.	faintly vegetable and earthy.	faintly earthy.
Remarks		contains some clay and rust.		
Bacteria per C. C., May 25	185	18	15	186
Bacteria per C. C., May 26	175	17	10	193
Bacteria per C. C., May 27	lost.	20	10	205

BIOLOGICAL EXAMINATIONS, &c.—*Concluded.*

DATE OF COLLECTION, MAY 31, 1897.

Number of Sample.	92	93	94	95
	Applied Water.	Effluent Sand Tank.	Effluent Sanit'n Co.'s Bed.	Effluent Sanit'n Co.'s Pan.
Dialomaceae:				
Asterionella	16			
Synedra	15.5	1.5	2	1.5
Cyclotella	2	1		
Navicula	2.5			
Melosira	6			
Cymbella	1			
Chlorophyceae:				
Protococcus	6			
Fungi:				
Mould			6	
Spores			6	
Rotifera.				
Rotifer	24			
Miscellaneous:				
Worm				6
Total	73	2	14	7
Amorphous	130	36	64	54
Odor	slightly vegetable and earthy.	none.	none.	faintly earthy.
Remarks			contains considerable clay and amorphous matter.	contains considerable rust.
Bacteria per C. C., May 28	170	19	41	no sample.
Bacteria per C. C., May 29	185	16	24	43
Bacteria per C. C., May 30	184	18	13	67
Bacteria per C. C., May 31	193	18	12	165
Bacteria per C. C., June 1	194	12	16	217
Bacteria per C. C., June 2		14	53	160

TABLE

SHOWING AVERAGE NUMBER OF

BACTERIA

IN APPLIED WATER AND EFFLUENTS; ALSO PERCENTAGE REMOVED.

TIME.	SAND FILTER.				SANITATION CO.'S FILTER.							
		AVERAGE NUMBER OF BACTERIA.				AVERAGE NUMBER OF BACTERIA.				AVERAGE NUMBER OF BACTERIA.		
1897.	Number of Samples.	Applied Water.	Effluent.	Per Cent. Removed.	Number of Samples.	Applied Water.	Effluent of Bed.	Per Cent. Removed.	Number of Samples.	Applied Water.	Effluent of Pan.	Per Cent. Removed.
April 24 to May 7	9	695	115	83.5	17	689	169	75.5	17	689	379	45 0
May 8 to May 15	7	710	140	80.3								
May 16 to June 1	16	174	30	82.8	15	176	43	75.6	15	174	173	00.6

NOTE.—From April 24 to May 7, the sand filter was running at the rate of 3.63 million gallons per acre per day; and from May 8 to June 1, at the rate of 4.20 million gallons per acre per day.

The Sanitation Company's filter was running at the rate of 11.8 million gallons per acre per day during the above periods. From April 24 to May 15, Antietam water was filtered. From May 16 to June 1, Maidencreek water was filtered.

TABLE

SHOWING

Total Organisms and Amorphous Matter

IN APPLIED WATER AND EFFLUENTS; ALSO, PERCENTAGE REMOVED.

STANDARD UNITS PER C. C.

DATE OF COLLECTION.	ORGANISMS.				AMORPHOUS MATTER.			
	Applied Water.	Effluent Sand Tank	Effluent Sanitation Co.'s Bed.	Effluent Sanitation Co.'s Pan.	Applied Water.	Effluent Sand Tank	Effluent Sanitation Co.'s Bed.	Effluent Sanitation Co.'s Pan.
April 24	450	11	4	3	336	84	112	98
" 25	398	3	15	3	108	58	86	78
" 27	179	4	15	16	144	36	112	52
" 29	328	21	11	3	180	50	62	68
" 30	395	1	4	1	254	50	62	62
May 1	391	2	8	31	224	46	90	60
" 3	299	4	144	41	188	50	64	52
" 6	78	8	32	9	140	42	68	62
" 10	259	43	17	19	134	44	54	54
" 13	396	14	27	5	146	40	60	56
" 17	231	6	13	22	134	36	58	48
" 21	105	2	19	1	134	38	48	46
" 24	53	5	5	13	102	34	52	46
" 27	54	9	2	7	124	40	60	52
" 31	73	2	14	7	130	36	64	54
Totals	3,689	135	330	181	2,478	684	1,052	888
Average	246	9	22	12	165	46	70	59
Percent. removed		96.3	91.0	95.1		72.4	57.5	64.2

EXPERIMENTS

WITH

BACILLUS PRODIGIOSUS.

By F. S. HOLLIS.

Bacillus Prodigiosus culture applied, contained 36,000,000 per cu. centimeter.

Amount added every hour from 12.30 to 9.30 P. M., June 1, 1897,

Sand Tank (rate 4 million gallons) 40.3 c. c. diluted to 500 c. c.
San. Co.'s Tank (rate 12 mil. gal.) 109.0 c. c. diluted to 500 c. c.

Bacteria in applied water at time of first application 194 per c. c.

Bacteria Per C. C. in Effluents

During Experiment.

Column 1—Time P. M. 2—Total Bacteria. 3—Bacillus Prodigiosus.

Date.	Effluent Sand Tank.			Effluent Sanitation Co.'s Bed.			Effluent Sanitation Co.'s Pan.		
	1	2	3	1	2	3	1	2	3
June 1......	12.26	12	0	12.23	16	0	12.20	217	0
"	1.30	10	0	1.30	23	0	1.30	not	taken.
"	2.00	15	0	2.00	15	0	2.00	not	taken.
"	2.30	14	0	2.30	530	0	2.30	508	0
"	3.00	16	0	3.00	660	2	3.00	430	4
"	3.30	11	0	3.30	30	0	3.30	400	1
"	4.00	23	0	4.00	101	1	4.00	352	4
"	5.00	13	0	5.00	76	1	5.00	260	3
"	6.00	35	0	6.00	120	6	6.00	360	6
"	7.00	28	0	7.00	38	8	7.00	356	7
"	8.00	28	0	8.00	45	12	8.00	216	9
"	9.00	41	0	9.00	41	8	9.00	263	6
"	10.00	20	0	10.00	140	13	10.00	230	7
June 2, A. M.	10.00	14	1	A. M. 10.00	53	9	A. M. 10.00	160	11

TABLE

SHOWING

Interval Between Scrapings

OF

EXPERIMENTAL FILTERING TANKS;

ALSO QUANTITIES FILTERED.

Pennsylvania Sanitation Company's Tank.

TIME BETWEEN SCRAPINGS.						QUANTITY FILTERED.		
From	To	Days.	Hours.	Min'tes	Days and fractions.	Between scrapin's, cubic feet.	Rate per day thr'h filters, c. ft	Rate per acre p. d. mil. gal.
April 12	April 18	5	10	00	5.417	1324.0	244.4	11.7
" 18	" 23	5	03	20	5.139	1231.7	239.7	11.4
*" 24	May 9	14	09	45	14.406	3603.3	250.1	11.9
†May 10	" 18	8	05	40	8.236	2011.0	244.2	11.6
" 19	" 27	8	06	00	8.250	2079.7	252.1	12.0
" 28	June 12	14	22	30	14.937	3708.7	248.3	11.8
June 14	" 21	7	04	45	7.198	1770.8	246.0	11.7
" 22	" 26	4	01	00	4.042	962.9	238.2	11.4
" 27	July 9	12	07	45	12.323	3011.4	244.4	11.7
July 13	" 19	6	09	30	6.396	1437.8	224.8	10.7
" 24	" 29	5	07	00	5.292	1321.5	249.7	11.9
Aug. 5	Aug. 14	8	12	45	8.531	1805.4	211.6	10.1
" 16	" 23	7	7	10	7.298	1737.2	238.0	11.3
Totals....	....	107	11	10	107.465	26005.4		
Averag's	....	....	....	....	8.267	2000.4	242 0	11.5

Sand Tank.

From	To	Days.	Hours.	Min'tes	Days and fractions.	Between scrapin's, cubic feet.	Rate per day thr'h filters, c. ft	Rate per acre p. d. mil. gal.
April 9	May 7	27	21	30	27.896	2131.3	76.4	3.63
†May 7	June 12	35	23	30	35.979	3168.1	88.1	4.20
June 14	July 15	30	14	00	30.583	2657.3	86.9	4.14
July 24	Aug. 21	28	15	00	28.625	2443.9	85.4	4.07
Totals....	....	123	2	00	123.083	10400.6		
Averag's	....	....	....	....	30.771	2600.1	84.5	4.03

*Shut off nearly one day on account of extending drip pan.

†Previous to May 15, water from Antietam Lake was used on filters. After May 15, water from Maidencreek was used on filters, after being stored in Hampden Reservoir.

EXPERIMENTS

TO DETERMINE WHETHER THE UNPLEASANT TASTE AND ODOR OF THE ANTIETAM WATER COULD BE REMOVED BY FILTRATION.

During the latter part of August, 1897, the water from Antietam Lake became very offensive to the taste and smell. The water was then turned onto the experimental filters. At no time during the test could the disagreeable odors or tastes be detected in the effluents of the filters, thus showing that these objectionable tastes and odors can be removed by filtration.

In order to ascertain the cause of these tastes and odors, samples taken from the surface of Antietam Lake, from the inlet to filters, and from the effluents of filters, were sent to Mr. F. S. Hollis, Bacteriologist, for investigation.

The results of his examinations appear in the following table. In his remarks, on the results, he says: "The Anabaena is the important organism in the lake and applied water, and is the one which is causing the trouble, by imparting its characteristic odor. It is generally a surface growth, which probably explains the smaller amount present in the applied water, which is, I believe, drawn off at some depth below the surface. The larger amount of amorphous matter seems to indicate that some may also have died in the pipe. The organisms are as usual mainly removed in the effluents, and but little odor remains."

ANABÆNA (CYANOPHYCEÆ)

MAGNIFIED 485 DIAMETERS

Microscopical Examination of Antietam Water.

By F. S. HOLLIS.

Date of Collection, August 30, 1897.
Date of Examination, September 1, 1897.

	Surface Antietam Lake.	Applied Water. (Antietam.)	Effluent Sand Tank.	Effluent Sanit'n Co.'s Pan.
Diatomaceae :				
Asterionella.........	7	12		
Cyclotella...........	36	42		1
Navicula.............	3			
Gomphonema......		3		
Synedra.............	34	87		
Tabellaria...		8		
Chlorophyceae :				
Scenedesmus.......	64	80		
Gonium..............	9			
Pediastrum.........	15			
Pandorina...........		24		
Protococcus.........		18		
Desmideae :				
Staurastrum		14		
Cyanophyceae :				
Anabaena...........	2085	639		
Clathrocystis.......	120	60		
Microcystis.........	36	48		
Infusoria :				
Cercomonas.........	6	6	2	2
Ceratium............	144	36		
Chloromonas.......	3			
Codonella...........	18			
Glenodinium.......	21	72		
Monas...............	1			
Peridinium.........	318	360	12	21
Trachelomonas....	21	27		
Rotifera :				
Rotifer....		72		
Total..............	2941	1608	14	24
Amorphous...........	375	1005	34	68
Color....................	.27	.25	.15	.20
Turbidity..............	distinct.	distinct.	very slight.	slight.
Sediment...............	considerable	considerable	none.	slight rust.
Odor.....................	Vegetable. Ch'r'cteris ic odor of anabaena dist'ct	Vegetable. Odor of anabaena.	faintly earthy.	slightly earthy and sweetish.

APPENDIX "B."

EXAMINATIONS OF WATER SUPPLIES.

CHEMICAL ANALYSES OF WATER SUPPLIES.

By H. W. Clark.

In Parts Per 100,000.

Samples collected, 1897.	April 24.	April 24.	April 24.	April 24.	April 24.	April 24.
Analysis made......	April 28.	April 28.	April 28.	April 28.	April 28.	April 28.
Number of corresponding Biologic'l Sample.	2	3	1	6	7	8
Sources.	Maiden-creek above Willow Creek.	Willow Creek at Davies' Mill Dam.	Maiden-creek at Pump'g Station.	Antietam East Stream.	Antietam West Stream.	Antietam near Overflow.
Temperature[Fahr]		67	65	65	63	64
Turbidity.............	very slight.	none.	none.	none.	none.	none.
Sediment.............	very slight.	slight.	slight.	very slight.	slight.	very slight.
Color..................	0.15	0.10	0.15	0.19	0.21	0.21
Odor..................	very slight.	none.	very slight.	very slight.	very slight.	none.
Total solids (in 100,000)	9.10	15.20	9.30	9.40	9.40	7.20
Hardness.............	6.10	11.30	6.90	3.50	2.60	2.50
Chlorine..............	0.14	0.18	0.14	0.12	0.11	0.11
Free Ammonia......	0.0024	0.0038	0 0046	0.0028	0.0010	0.0056
Albuminoid Am'ia	0.0090	0.0068	0.0082	0.0128	0.0110	0.0150
Nitrogen as nitrates	0.0980	0.1410	0.0980	0.0570	0.0500	0.0460
Nitrogen as nitrites	0.0004	0.0006	0.0006	0.0000	0.0002	0.0002
Oxygen consumed..	0.0600	0.0100	0.0500	0.1500	0.1700	0.2400

CHEMICAL ANALYSES

OF WATER SUPPLIES.—Continued.

BY H. W. CLARK.

IN PARTS PER 100,000.

Samples collected, 1897.	April 24.	April 24.	June 2.	June 2.	June 2.	June 2.
Analysis made......	April 28.	April 28.	June 4.	June 4.	June 4.	June 4.
Number of corresponding Biologic'l Sample.	4	5	96	97	98	99
SOURCES.	Bernhart Influent	Bernhart Reservoir near overflow	M'Kentley's Spring.	Bernhart Reservoir at Pier.	Egelman Influent	Egelman Reservoir near overflow
Temperature[Fahr]	66	61				
Turbidity.............	very slight.	very slight.	none.	slight.	slight.	slight.
Sediment	slight.	very slight.	very slight.	decided.	decided.	decided.
Color..................	0.20	0.17	0.00	0.25	0.18	0.26
Odor..................	none.	none.	none.	none.	none.	none.
Total solids (in 100,000)	8.90	8.80	13.00	9.50	9.00	8.20
Hardness............	2.90	5.10	8.90	4.10	2.00	1.80
Chlorine..............	0.1100	0.1200	0.1400	0.1000	0.1900	0.1800
Free Ammonia......	0.0040	0.0056	0.0008	0.0040	0.0002	0.0026
Albuminoid Am'ia	0.0138	0.0146	0.0016	0.0156	0.0078	0.0108
Nitrogen as nitrates	0.0100	0.0330	0.0560	0.0110	0.0300	0.0250
Nitrogen as nitrites	0.0000	0.0002	0.0000	0.0002	0.0000	0.0000
Oxygen consumed..	0.1700	0.1300	0.0100	0.2200	0.1500	0.2000

BIOLOGICAL EXAMINATIONS

OF WATER SUPPLIES.

By F. S. Hollis.

Maidencreek.

Standard Units Per C. C.

Date of collection, 1897	Apr 24	Apr 24	Apr 24	May 5	M'y 11	M'y 11	M'y 17
Number of sample	2	3	1	45	55	54	67
Source.	Maid'n cr'k ab. Willow creek.	Willow Cr'k at Davies' Dam.	Maid'n creek at P'mp'g Station	Maid'n creek at P'm'ng Station	Maid'n c'k inl't H'pden res'rv'r	Hampden Reservoir.	Maid'n c'k inl't H'pden res'rv'r
Diatomaceae :							
Navicula	6.5	5	10	19.5	7	1	23
Synedra	11	18	15	21	27.5	17	21
Cyclotella	0.5		0.4	1			1
Melosira			10				
Gomphonema			2.4				
Pinnularia				4			
Tabellaria				8			
Cymbella					4		9
Asterionella						5.5	3
Chlorophyceae :							
Spirogyra					60		40
Pandorina						12	
Desmideae :							
Cosmarium			6				
Staurastrum	6		3				
Closterium	6				8		
Cyanophyceae :							
Oscillaria							10
Infusoria :							
Monas	0.5						
Codonella						12	
Chloromonas						2	
Trachelomonas						2	
Rotifera :							
Conochilus						8	
Anuraea						96	
Rotifer						80	
Miscellaneous: :							
Vegetable fibre	12			40			
Total	42	23	47	93	106	235	107
Amorphous	194	294	158	264	348	104	530
Odor	vegetable and earthy.	earthy and unpleasant.	veg'ble and aromatic	veg'ble and earthy	slightly vegetable	vegetable and earthy	slightly vegetable
Remarks	contains considerable clay.	cont'ns few l'rg pieces vegmatsm clay		contn's much clay t'k soon aft hv rain	contains much clay.		sample t'ken at lower end of ov'rfl'w
Bacteria per C. C.	286	365	292	1174	330	238	860
			At upper end of overflow				826

Biological Examinations of Water Supplies.—*Continued.*

Antietam.

Date of Collection	Apr 24	May 6	Apr 24	May 6	Apr 24	May 6	M'y 19	M'y 19
Number of sample	6	47	7	46	8	48	73	74
Source.	East Stream	East Stream	West Stream	West Stream	Lake near over-flow.	Lake near over-flow.	Lake at Gate House.	Bottom of Lake at Gate House.
Diatomaceae :								
Melosira.........	32							12
Navicula	7	12	3	4	1.5	2.5		5
Synedra..	70	18	25	5	12	15	2.5	19.5
Pinnularia........	12		10	12				
Cyclotella........	2		1	2	29	1	1	6.5
Asterionella					257.5	11	157	17
Gomphonema ..				1.5				
Surirella				2		6		
Cymbella.........		1		8				
Chlorophyceae :								
Scenedesmus ...							2.5	5
Protococcus					4	50	16	4
Pandorina........					42	238	260	
Closterium							1.5	
Spirogyra		380						
Conferva.			220	160				
Raphidium.				0.5				
Desmideae :								
Staurastrum. ...		6			18	3		
Cyanophyceae :								
Microcystis......					2			
Infusoria .								
Chloromonas. ..		1			7	36	1	
Monas							2	
Codonella........						12		
Ceratium.........							20	
Cercomonas.....							6	6
Rhizopoda .								
Arcella...........				8				
Actinophrys					56			
Rotifera :								
Anuraea..........							48	
Conochilus						6		
Rotifer...........					100	36	112	
Miscellaneous :								
Crustacean							80	
Vegetable fibre..		40		40			20	40
Total...........	123	458	259	243	529	416	729	115

BIOLOGICAL EXAMINATIONS OF WATER SUPPLIES.—*Continued.*

Antietam.—CONCLUDED.

Date of Collection	Apr 24	May 6	Apr 24	May 6	Apr 24	May 6	M'y 19	M'y 19
Number of sample	6	47	7	46	8	48	73	74
SOURCE.	East Stream	East Stream	West Stream	West Stream	Lake near over-flow.	Lake near over-flow.	Lake at Gate House.	Bottom of Lake at Gate House.
Amorphous	450	340	430	580	268	268	660	700
Odor	earthy and slightly vegetable.	earthy.	very faintly vegetable.	vegetable and earthy.	slightly vegetable and earthy.	vegetable.	vegetable.	vegetable and earthy.
Remarks.		contains considerable clay.	conferva and Uloth'x grow'g on bed of str'm	cont'ns much clay & amorphous matter.	contains considerable clay.	contains considerable clay.		
Bacteria per C. C.	700	850	720	2925	62	580	116	445
Bacteria per C. C. 15 feet below surface							312	
Bacteria per C. C. 34 feet below surface							445	

BIOLOGICAL EXAMINATIONS OF WATER SUPPLIES.—*Continued.*

Bernhart.

Date of collection	Apr 24	M'y 11	M'y 17	Apr 24	M'y 17	M'y 11	M'y 17	June 2
Number of sample	4	56	68	5	70	57	69	97
SOURCE.	B'rnh't influ'nt	B'rnh't influ'nt	B'rnh't influ'nt	B'rnh't res ne'r over-flow	B'rnh't res ne'r over-flow	B'rnh't res'rv'r at Pier.	B'rnh't res'rv'r at Pier.	B'rnh't res'rv'r at Pier.
Diatomaceae :								
Cymbella	13				2	2	1	
Synedra	13	2	1.5	100.5	123	263	115	11
Navicula	8.5		2.5	2	1	2		4
Melosira	60		10		10			
Cyclotella	2			11.5				7
Pinnularia	1							
Asterionella			2.5		13	34.5	20	57
Gomphonema				1.5	1		0.5	
Chlorophyceae :								
Stigeoclonium		10						
Pandorina				44	16	136	68	
Protococcus				26		14	16	4
Scenedesmus					45		52	
Raphidium						2.5		
Pediastrum								28
Cyanophyceae :								
Oscillaria		14						
Infusoria :								
Chloromonas	1			3	52	1	44	
Codonella				144				90
Cercomonas				18	4		4	
Monas				0.4	1.5			
Cryptomonas							4	
Trachelomonas							2	
Rhizopoda :								
Actinophrys				12				
Rotifera :								
Rotifer				20	154		88	78
Anuraea					24		48	72
Conochilus						10	16	10
Miscellaneous :								
Vegetable fibre		80	50					
Total	99	106	66	383	446	465	478	361
Amorphous	780	670	550	190	460	480	368	160
Odor	faintly veg and earthy	vege-table and earthy	vege-table and earthy	vege-table	veg and slightly aro-matic	veg and slightly aro-matic	vege-table	slightly veg'ble and earthy
Remarks	contn's many plant stalks	cont'ns much fragm'l and amorpho's	cont'ns cons'bl' clay & amor'h ous mat		cont'ns much clay		cont'ns much clay	
Bacteria per C. C.	1150	700	896	1806	295		350	

BIOLOGICAL EXAMINATIONS OF WATER SUPPLIES.—*Continued.*

Egelman and McKentley's Spring (Bernhart).

Date of collection	Apr 27	M'y 19	June 2	Apr 27	M'y 19	June 2	M'y 11	June 2
Number of sample	21	71	98	22	72	99	58	96
SOURCE.	Egel-man In-fluent.	Egel-man In-fluent.	Egel-man In-fluent.	Egelm res ne'r over-flow.	Egelm res ne'r over-flow.	Egelm res ne'r over-flow.	Mc-Kent-ley's Spring.	Mc-Kent-ley's Spring.
Diatomaceae :								
Synedra	3	7	17	2	24	8.5	2	2
Pinnularia	8		6					
Navicula	2	4	7	2	11	5		1
Cyclotella		1	1.5	6	11	2.5		
Cymbella		1	1					
Surirella			4					
Tabellaria				3				
Gomphonema						4		
Chlorophyceae :								
Spirogyra	10			182				
Protococcus			6			8		
Conferva								20
Desmideae :								
Staurastrum					3			
Cyanophyceae :								
Oscillaria			10	36				
Infusoria :								
Monas		0.2	0.25			0.5		
Cercomonas		1						
Peridinium				12				
Dinobryon					38	221		
Rotifera :								
Rotifer				24				
Miscellaneous :								
Vegetable fibre		20		20	10		20	
Total	23	34	53	287	97	249	22	23
Amorphous	364	500	520	176	256	242	28	74
Odor	faintly vege-table.	none.	distinct ly vege-table.	faintly vege-table.	none.	slightly v'g'tble and earthy.	none.	none.
Remarks								sample cont'ns a little rust.
Bacteria per C. C.	135	355		264	135		57	

Biological Examinations of Water Supplies.—*Concluded.*

Sacony Creek at Kutztown, etc.

Date of collection	M'y 26	M'y 26	M'y 26	M'y 26	M'y 26	M'y 11	Apr 29	Apr 28
Number of sample	83	84	85	86	87	53	28	23
SOURCE.	Sacony Creek ab Kutztown St NorSch Sewer Outlet.	Sacony C'k 150 feet bel Kutztn St N Sch Sewer Outlet.	Sacony Cr'k 100 feet bel Slaughter House.	Sacony Creek 50 feet below tann'ry	Sacony Creek second bridge below tann'ry	Hampden Spring	Penn Street Reservoirs.	Distrib System Low Service Court st n'r 7th.
Diatomaceae:								
Synedra	131.5	110	135.5	117	137	1	75.5	240
Navicula	43.5	32.5	43	57	51		3.5	5
Cymbella	3	4	3	1	4			
Cyclotella	6.5	6.5	7.5	13.5	5.5		9	7.5
Melosira	10	16	40	10	44			
Gomphonema	2	6	18	6	24			
Pinnularia	6		6					
Asterionella							188	5.25
Pleurosigma							1	1
Surirella								8
Chlorophyceae:								
Protococcus	4	10					48	60
Pandorina							120	26
Raphidium							6	
Spirogyra	210	200	420	240	160			
Scenedesmus		8						
Desmideae:								
Staurastrum					3			
Cyanophyceae:								
Oscillaria	28		10		16			
Infusoria:								
Trachelomonas	2							
Monas	0.5		0.2	0.2	0.2			0.2
Chloromonas	2		1	2	1			4
Ceratium							12	
Peridinium							4	
Cercomonas								8
Rhizopoda:								
Actinophrys								16
Rotifera:								
Rotifer							48	
Anuraea							60	190
Miscellaneous:								
Vegetable fibre		40		40				
Crustacean frag								40
Total	449	433	684	487	446	1	575	611

Biological Examinations of Water Supplies.—*Concluded.*

Sacony Creek at Kutztown, etc.—Concluded.

Date of collection	M'y 26	M'y 26	M'y 26	M'y 26	M'y 26	M'y 11	Apr 29	Apr 28
Number of sample	83	84	85	86	87	53	28	23
Source.	Sacony Creek ab Kutztown St NorSch Sewer Outlet.	Sacony Cr'k 150 feet bel Kutztn StNSch Sewer Outlet.	Sacony Cr'k 100 feet bel Slaughter House.	Sacony Creek 50 feet below tann'ry	Sacony Creek second bridge below tann'ry	Hampden Spring	Penn Street Reservoirs.	Distrib System Low Service Courtst n'r 7th.
Amorphous	268	230	276	290	264	18	170	180
Odor	vegetable and earthy.	vegetable and earthy.	vegetable and earthy.	slightly vege. and earthy.	vegetable and earthy.	none.	d'cid'ly veg'ble and oily.	vegetbl and slightly oily.
Remarks	cont'ns much d't'ch'd algae growth mainly spir'g'a	2,123,900 bact'ri' per c. c. in sewage frm Sewer Outlet				cont'ns a little clay.	Sample cont'ns much fragm'l mater'l	Sample taken f faucet nr dead end in water main.
Bacteria per C. C.	750	13,740	5,526	3,105	2,900	5	77	347

Bacteria per C. C. May 11, 1897, in Hampden Drift water, 122.

OPINIONS

—OF—

ERASTUS G. SMITH, Professor of Chemistry of Beloit College, Beloit, Wisconsin.

W. P. MASON, Prof. of Chemistry, Rensselaer Polytechnic Institute, Troy, New York.

RUDOLPH HERRING, Consulting Engineer, New York.

[Copy.]

THOMAS M. THOMPSON,

Director Board of Public Works,

Philadelphia, Pa.:

DEAR SIR:

In reply to your inquiry under date of July 15th, concerning the purification of waters by filtration, I beg leave to submit the following as an expression of opinion formed from study and research upon the general problem, and especially from personal examination of filtration plants as they have been installed and successfully operated on a large scale in the larger European cities.

The problem of the economical and efficient filtration of waters on the large scale for domestic use is one of the most serious presented to any municipal body, and any suitable complete discussion would far out-reach the limits of this brief communication.

It is now about fifty years since the first attempts were made at London to purify the waters for that metropolis, by filtration. The aim was then merely to deliver a bright, clear water. It was my fortune to see recently this first filter bed still in operation, the same having been used continuously, and with practically no expense for repairs, since its first construction—a striking illustration of the desirability of thorough work in all engineering enterprises. Equally striking is the fact that the type of filter thus first built has been retained from the first, and those most recently constructed in London, and now under process of construction there and on the Continent, are of the same form and plan. Such differences as do exist are merely those of detail, as *e. g.*, the slope of the wall,

character of the sand used, under drainage, etc. The system has spread to other portions of England and the Continent until most of the important large European cities have adopted this form of filter for the satisfactory and efficient purification of their water supplies. Paris, Antwerp, Berlin, Hamburg, were among the most important places visited this summer.

In the process of slow sand filtration all filter beds are constructed in exactly the same manner. A basin with strong retaining walls, covering an area from about 0.5 to 1.6 acres, the sides and bottom of the basin being coated with heavy cement to prevent both the escape of the filtered waters and the admixture with the filtered waters of natural "land-waters." Such basins are usually about 9 feet in depth. Upon the cement floor is placed a series of canals made from tile or brick laid loosely together for the purpose of collecting the filtered waters into a central pipe, discharging into the main pump well. Upon these are placed successively a layer of coarse broken stone, then a layer of coarse gravel, then a layer of fine gravel and finally a layer of sand, usually from 24 to 36 inches in thickness. The specifications for two new beds, now under process of construction at Paris, distribute these relative beds as follows:

Fine sand	10	inches
Coarse sand	10	"
Fine gravel	4	"
Coarse gravel	6	"
Bricks and broken stone	8	"

These beds at Paris are somewhat thinner than usually constructed in England, but the proportions between the layers are quite the same, and careful daily analyses and examinations have proven them to be quite as efficient.

Upon the surface thus prepared the water quietly flows, and gradually settles down through the sand. When the process is properly conducted, effluent waters are bright, clear, are grealtly improved chemically, and careful examination shows them to have lost all, even the lowest and most minute forms of life. The filtering process continues until the surface of the bed becomes coated with a layer from the sediment and flotant matters contained in the waters, which finally completely clogs and prevents further passage of the water. The beds are then allowed to drain, this superficial layer removed, the beds cleaned and smoothed over, and the waters again admitted. This process is so simple it can be understood by anyone. There is no expensive and complicated machinery to install and

keep in repair, no chemicals are essential to the process, or used, and yet it requires the utmost care in supervision. It is a distinctly scientific process, and its efficiency and success depends upon a most careful scientific supervision. The more careful this supervision, the better results obtained. No system of filtration will operate itself, and this process least of all. The services of an expert chemist are necessary. Perhaps the most interesting plant I have seen is at Berlin, at the works at Muggelsee. Here are 22 filters with a combined area of 12.7 acres, delivering a maximum of twenty-three million gallons of water per diem. Each filter is separate, covered with a vaulted roof. Analyses of the water are made daily. No water is admitted to the mains until it has reached the degree of purity demanded by the German health regulations, and if at any time the number of bacteria exceed the limits allowed the bed is immediately cut off, cleaned and not again put into service until the standard is reached. Generally speaking, with river waters in their normal condition, filter beds need scraping and cleaning once every three to six weeks. A multiplication of beds secures greater uniformity in quality of water discharged, so that thus serious fluctuations and variations in the supply are avoided. The system of slow sand filtration has proved itself satisfactory on the large scale, on that there is but one voice. Difficulties have been encountered, but as they have arisen they have been overcome, until there is but one opinion among those operating and, therefore, most conversant with such plants, viz.: That for treating waters on the large scale this is the only method which has proved satisfactory.

It is not the purpose of this communication to explain fully the theory and action of these beds. What you ask is simply an expression of my opinion based on such studies as I have been able to make, and observation on foreign works in actual operation. But yet, it is of the utmost importance for us to inquire, what is the efficiency of these beds? And what assurance can we have that a similar system will grant the needed purification of the waters and guarantee protection to the consumers? I will not attempt to re-array the figures proving beyond all question the protection offered to a community by the use of such a system of filtration of its water supply. Modern science recognizes that system of filtration only as effective which removes the minute micro-organisms from a water. A water may be clear, the organic matters may be reduced to a minimum; but unless, also, the process shows a practical removal of micro-organisms (or more popularly the removal of the "bacteria," or "microbes," or "germs"), the

system fails. Did space allow, I would take pleasure in quoting to you the data issued by foreign Health Boards and examiners bearing on this most important point; all of which agree in this, that a water however dirty and wholesome is rendered practically sterile and suitable for domestic use by the process of slow sand filtration intelligently operated. I will, however, make one such quotation, and that from the last

Report of the results of analyses of the Metropolitan Water Supply undertaken during May, 1897, by Sir E. Frankland, K. C. B., F. R. S., on behalf of the Local Government Board.

These analyses are made by Sir E. Frankland, in behalf of the Local Government Board for the City of London, and reports made monthly. There is probably no higher authority in the world than Sir E. Frankland, and due weight should be given to his official utterances.

Regarding the Thames River, he says: "The Thames at Hampton was, on May 5th, turbid and pale yellow in color; it was of fairly good chemical, but indifferent bacterial quality. The water supplied by five companies drawing from this source was, in every case, efficiently filtered before delivery, but three out of fourteen samples collected infringed the standard of 100 microbes per c. c. The bacterial improvement effected by the varions companies is expressed by the following percentage numbers: Chelsea, 99.88; West Middlesex, 99.62; Southwark, No. 4 filter well, 99.91; No. 5 filter well, 98.37; Grand Junction, general filter well at Hampton, 98.64; general filter well at Kew, 97.58; south filter well at Kew, 99.52; and Lambeth, 99.59."

Regarding the New River: "The New River cut, before entering the storage and subsidence reservoirs of the New River Company, was, on May 6th, turbid and very pale yellow in color. It was of excellent chemical, but not good bacterial quality. After efficient filtration, it was delivered to consumers in most excellent chemical and bacterial condition, surpassing in respect of organic purity the majority of deep well waters. The bacterial improvement is represented by the following percentage numbers: General filter well, 98.81; No. 2 filter well, 99.41; and No. 4 filter well, 99.21."

Regarding the water from the Lea: "The water taken from the Lea at Angel Road, by the East London Company, was turbid and very pale yellow. It was, in respect to chemical quality, exactly equal to that of the Thames at Hampton, but

was much inferior in bacterial quality. After efficient filtration, it was delivered to consumers in a high degree both of organic and bacterial purity. The bacterial improvement effected by this company amounted to the following percentage numbers: No. 1, Essex filter wells, 99.15; No. 2 Essex well, 99.75; and Middlesex well, 99.56.

As is well known to you, London draws its supply mostly from the above rivers, which is delivered to the city through seven companies. The average daily supply to the City of London during May of this year was 247,155,978 United States gallons, an average consumption per capita of 43.4 United States gallons. The relative proportions from various sources for this vast supply were as follows:

From the Thames	56.20	per cent.
" " Lea	27.02	"
" springs and wells	16.65	"
" ponds	.13	"

It may be added that the water from ponds is not used for drinking and domestic purposes; the water from springs and wells is from the Kent deep chalk wells, a hard but otherwise very satisfactory water, so that eighty-three per cent., or more than 205,000,000 gallons of water, was taken daily from the rivers, and satisfactorily filtered, before delivery to the City of London, during the month of May.

As corroborating above report I quote from the report of the chemists of the company, of Sir William Crookes and Professor James Dewar, concerning their examinations of the waters delivered by the companies during May, 1897:

"The results of our bacteriological examinations of 258 samples are recorded in the following table; we have also examined sixty-nine other samples, taken from special points either at the different filter beds or at stand-pipes:

Thames water, unfiltered (mean of 26 samples) .... 2,937 microbes per c. c.

Thames water, from the clear water wells of five Thames derived supplies (mean of 28 samples).. 40 microbes.

Thames water, from the clear water wells of five Thames derived supplies (mean of 128 samples) highest........ 233 microbes.

Thames water, from the clear water wells of five Thames derived supplies (mean of 128 samples) lowest........ 10 microbes.

New River, unfiltered (mean of 26 samples).......791 microbes.

New River, filtered (mean of 26 samples).......... 44 microbes.

River Lea, unfiltered (mean of 26 samples)........388 microbes.

River Lea, from the clear water well of East London Water Co. (mean of 24 samples)............68* microbes.

*Two additional samples abnormal.

The water supplied to the City (not environs) of Paris is brought from different springs, but the supply is inadequate during the summer months. Large filters have been constructed at St. Maur to filter the water of the Marne, with view to introduction into the city. These have been in operation for more than a year now, under the direction of M. Cranmoisan acting under the Prefect of the Seine. Results have not yet been put in print, but records of the action of the filters, kindly shown me, are quite as favorable as those given above from London. This plant interested me greatly, as the beds are thinner than those in general use. Built after plans of beds when the Anderson method of preliminary treatment of waters was in use, it was designed originally to add this system later; but so satisfactory have been the results with simple filtration this year, and so much more economical the operation, M. Cranmoisan informs me, that all idea of adding the Anderson system to the plant has been abandoned.

At Antwerp, simple filtration *without any preliminary treatment of the waters with iron has given for about eighteen months now most satisfactory results.*

At Berlin the number of bacteria, after filtration, is never allowed to reach the limit of 100 per cubic centimeter, fixed by the Government as standard.

At Hamburg, though using the more dirty Elbe water, the same degree of efficiency is maintained, as shown by the remarkably concordant results of investigation at the laboratories of both the Water Works Administration and the Health Board.

It is difficult to read such results obtained at these great water filtration plants, under both private and public control, and under such exceedingly diverse conditions, without becoming convinced that the system of slow sand filtration has an abundant weight of argument in its favor. It has passed beyond the stage of experiment. The unbiased and unprejudiced records secured concerning the action of the filter beds in purification of waters, attest the efficiency of the method, and are the best guarantee we can possibly have for the success of a plant constructed after the same principles and conducted in the same intelligent manner.

One of the most important questions in connection with the filtration of a public water supply, is that relating to the effect of same on the public health. Sanitary science has shown in recent years that some forms of disease are undoubtedly water-borne, notably cholera, typhoid fever, with great probability

that other forms are transmitted in the same manner. So important, however, is typhoid fever in this connection, that it is not infrequently taken as the measure of the purity or impurity of a supply, and the death rate from typhoid fever may fairly be taken as an index of the efficiency of filtration methods and other protective methods adopted. If we should take the space to tabulate the results from leading cities, at home and abroad, the most surprising fact developed would be that the best American supplies are higher in the death rate from typhoid fever than any European supply protected by filtration. This seems an extravagant statement, but one I believe practically borne out by actual statistics. The Engineering News for May 21, 1896, gives a table compiled by the eminent authority, John W. Hill, C. E., in which statistics for five years for 66 cities are quoted. According to this tabulation, accepted as authoratative, the city of Brooklyn stands at the head of all American large cities in its low typhoid fever death rate, viz.: 19 per 100,000, but yet it ranks 16 in the list quoted. New York stands 17; Davenport, Iowa, 18; New Orleans, 19; Milwaukee, 28; Boston, 30; Detroit, 31; Dayton, 32; Buffalo, 35; Providence, 36; Covington, 37; San Francisco, 38; Minneapolis, 40; Baltimore, 41; Newark, 42; St. Louis, 43; Newport, Ky., 44; Philadelphia, 45. I can quote the table only in part, merely showing the relation of Philadelphia to foreign well filtered supplies.

TYPHOID FEVER DEATH RATES IN AMERICAN AND FOREIGN CITIES, 1890–1894 INCLUSIVE.

CITY.	SOURCE OF WATER SUPPLY.	1890	1891	1892	1893	1894	Av.
1. The Hague...	Filtered from sand dunes...	3	12	4	2	3	4.9
2. Rotterdam...	Filtered from River Maas..	6	4	6	5	5	5.2
4. Dresden	Filter gallery by River Elbe	9	8	5	5	8	6.9
8. Berlin	Filtered from Lake Tegel and Muggel.........	9	10	8	9	4	8.0
9. Breslau...	Filtered from River Oder...	15	12	15	10	6	11.6
10. Amsterdam..	Filtered from Haarlam dunes...........................	19	11	15	16	9	13.9
13. London	Kent wells, 17 per cent.; filtered from Thames and Lea, 83 per cent............	16	15	11	16	15	14.6
14. Edinburgh...	Filtered from reservoir in Pentland Hills..............	19	18	13	14	15	15.8
21. Hamburg.....	From River Elbe, filtered since May, 1893.	28	23	34	18	6	21.8
25. Paris	Rivers Seine, Marne, Vanne Ourque, Canal Art, wells and springs..................	30	40	28	25	29	26.4
45. Philadelphia	Schuylkill and Delaware Rivers..................	64	64	40	41	32	48.2

Since the introduction of a system of filtration into Hamburg in 1893, the annual rate has fallen to correspond to other plants quoted above where filters were in operation during the whole period of five years cited. In the period of five years the average for Philadelphia is 48.2. In a previous communication I cited the rate for Philadelphia covering a period of 22 years. The annual reports of the Department of Health for Philadelphia show that from 1870 to 1891, there was an average death rate from typhoid fever in the city of 61.9 per 100,000 population, the highest being 92.2 in 1876 and the lowest 38.2 in 1879. Equally striking in this connection is the fact that the disease does not show its ravages for a period and then disappear, but is constant through all the years—the deaths representing never less than 1.94 per cent. of the whole number of deaths in any year or more than 4.03 per cent.

Such data as these (and I could extend them indefinitely did space permit) demonstrate beyond question that where the entire water supply is subjected to slow sand filtration, there typhoid fever is *practically stamped out.* Were this country subject to cholera epidemics I would repeat the argument for the protective influence of sand filtration against this dreaded scourge. The terrible experience of Hamburg in 1892–'93 proved the water-born nature of this disease. Hamburg with its population of 640,000, had 8,605 deaths from cholera. Altona, separated from Hamburg only by an imaginary line along one street, with a population of 143,000, had but 328 deaths. In the words of the eminent savant Dr. Koch, "cholera in Hamburg went right up to the boundary of Altona and stopped." Both cities took their water supply from the Elbe, but with this difference, the Altona supply was most carefully filtered before distribution, the Hamburg supply was delivered raw. The one city, protected by filtration of its water supply was immune to disease, the other, without such protection, exposed to its dreadful ravages. Profitting by this experience, most strenuous efforts were immediately put forth by the City of Hamburg, resulting in the installation of a system of slow sand filtration of the Elbe waters, one of the most admirably arranged I have ever seen, and which operated in a thorough, careful manner, furnishes a supply of the most acceptable character.

Concerning the future of simple slow sand filtration abroad, I could have but one opinion. It has proved so satisfactory that its extension by cities now using it and its adoption by others is only a question of time. At St. Maur two additional large beds are under process of construction for filtering water

from the Marne for the City of Paris. At Berlin, I chanced to meet the Engineer for the service at St. Petersburg, where filtration, already somewhat in use, is to be enlarged and perfected after the most modern improvements in the process. At London four additional large beds are in process of construction for the Grand Juuction Company. Immense reservoirs for impounding Thames waters for a population of London estimated to reach in 1941 more than twelve millions, and to require an amount of water upwards of 500 millions of gallons daily, are now under contract and one approaching completion. Opinion from authorities endorsing the system can be quoted. The Royal Commission says regarding the London supply:

CONCLUSION AS TO QUANTITY AND QUALITY.

"We are strongly of opinion that the water as supplied to the consumer in London is of a very high standard of excellence and of purity, and that it is suitable in quality for all household purposes. We are well aware that a certain prejudice exists against the use of drinking water from the Thames and the Lea, because these rivers are liable to pollution, however perfect the subsequent purification, either by natural or artifical means, may be; but having regard to the experience of London during the last 30 years, and to the evidence given to us on the subject, we do not believe that any danger exists of the spread of disease by the use of this water, provided that there is an adequate storage, and that the water is efficiently filtered before delivery to the consumers."

Such eminent authorities as Dr. Frankland, Dr. Ray Lancaster, Mr. Crookes, Dr. Odling, Dr. Percy Frankland have all testified to the wholesome character of the water derived from the basins of the Thames and the Lea, and by a comparison of the health statistics and death rate of other cities and large towns have proved that the quality of the present water supply to the Metropolis is entirely satisfactory, and that this excellence is likely to be maintained, and even, if possible, improved under careful and more extended supervision.

Reports are not yet in print from the filters at St. Maur for Paris, but opinions given by M. Cranmoisan already referred to, in connection with laboratory notes examined, are of the satisfactory nature of the filters there established. Herr Anklamm, Engineer in charge of the works for the City of Berlin, in view of experience with the filters of that city, and from data from more than sixty thousand analyses of the waters made at the filter laboratories in operation of the plants, expresses a most unqualified endorsement of the system. Herr Ad. Kenma, man-

ager of the works at Antwerp, expresses the same opinion. The management of the Hamburg plant the same.

Your communication asks for any information regarding mechanical filtration, and "if you have found in your experience the use of alum injurious to the human system." Regarding the use of alum, would say, the whole efficiency of mechanical filtration is based on use of it or similar salts. When rightly and intelligently used, no alum should be found in the filtered water. I have repeatedly advised its use at different points, but such use of alum must be very carefully supervised as I am of the opinion that alum in such filtered water is decidedly harmful, and hence objectionable.

As to mechanical filtration, I deem it inadvisable to enter into extended discussion at this time.

Mechanical filters are in use in this country at something over 100 points. All of these plants are smaller plants. I think the largest is at Denver, of capacity not to exceed 25,000,000 gallons per diem, and not operated to that extent. The capacity of some of the best known larger plants in operation is as follows:

5,000,000 at Quincy, Ill.

6,000,000 at Davenport, Iowa.

7,000,000 at Atlanta, Ga.

9,000,000 at Chattanooga, Tenn.

10,000,000 at Wilkesbarre, Pa. (Manual Am. Water Wks., 1897.)

It seems to me very clear, therefore, that the introduction of mechanical filters on any such gigantic scale, "capable of filtering not less than 300,000,000 gallons of water daily," as you state in your letter, would still remain so much of an experiment, and insure so many uncertainties, as not to justify the attempt in face of certain results obtained by other methods already proven successful, on scale commensurate with the demands of Philadelphia. Mechanical filters are cheaper to install, but much more expensive to operate.

As to experience with mechanical filters abroad, would say, that so far as my investigation went, I found only the Anderson method of revolving purifiers, using metallic iron, in use by private companies supplying the environs of Paris. At the only point where water is being filtered for the City of Paris itself, viz.: St. Maur, it was found as already stated that the process of slow sand filtration gave equally good results, and at less cost, and hence the management could see no reason why any mechanical system should be recommended.

At Antwerp, the Anderson system has not been used since a year ago last March, on account of the added expense, and re-

sults of the analyses are equally satisfactory. At all the other cities visited slow sand filtration is exclusively used.

Briefly, in conclusion, to your inquiry of the 15th of July, I would say, I have no hesitation in speaking clearly and firmly for the process of slow sand filtration for Philadelphia, Pa. It is the only system in use on the large scale abroad, and the repeated testimony by all who have given the problem careful study, is for the beneficent results of the same. I do not consider there can be any reasonable doubt but that if you introduce this system for the purification of your water supply under suitable supervision and control, the results obtained in other cities will be repeated, and the citizens of Philadelphia will be assured of a supply at once most satisfactory wholesome and safe to use.

Respectfully submitted,

(Signed) ERASTUS G. SMITH,

Professor Chemistry Beloit College.

BELOIT, Wis., September 10th, 1897.

(Copy.)

RENSSELAER POLYTECHNIC INSTITUTE.

TROY, N. Y., September 10, 1897.

MR. THOMAS M. THOMPSON,

Director of Public Works,

Philadelphia, Pa.:

Permit me to reply to your inquiry of recent date, as follows: For a filtering plant of the size you propose I have always leaned towards the form known as the English Filter Bed System, for the reason that such system has been in operation in many cities of Europe during a great number of years, and we are thoroughly acquainted with just what it will do and what its efficiency is. We know that such a system, if properly managed, will remove 99 or more per cent. of all bacteria present in the water, and we also know from voluminous statistics that cannot be contradicted, that such a removal of bacteria has resulted in a most marked lowering of the typhoid death rate. It is scarcely necessary for me to give you here a detailed description of the English plant or statistics with reference to its efficiency, cost and mode of operation ; allow me to refer you for all such information to the second edition of my work on "Water Supply" ; suffice it here to say that Europe

is abundantly satisfied with its sand filter beds, and their use is increasing, not diminishing. I make this latter statement because my attention has been incidentally called to a paragraph in the public press, which said that the London filters had been practically condemned; the writer of such statement was in decided error.

I have personally seen and carefully examined the London filters while working, upon more than one occasion, and I am in constant receipt of the latest returns showing their high efficiency.

With reference to mechanical filtration, with the use of alum, allow me to say, that I have seen very excellent results obtained by such plants, and I have had charge of extended experiments with them, which experiments were instituted in order to show just what such plants would do; the results were very satisfactory, and whenever such a plant was properly run, I could detect no trace of alum in the filtered water. I am in the habit of recommending the English filter bed or the mechanical filter plant according to the size of the town to be supplied and the local conditions to be met. For instance, I have recently advocated mechanical filtration for Troy, N. Y., and English filter beds for Albany. It seems to me that for small cities and towns the mechanical plant is more economical and efficient, but when called upon to supply a city requiring 300,000,000 gallons of water per day, we are confronted by very different conditions.

No mechanical plant, even approaching so large a size, has ever been constructed. You contemplate erecting the largest filtering plant in the world, larger than all of the great plants supplying the City of London put together. As already stated, no plant of the mechanical type has ever been constructed that at all approaches the vast size that your Philadelphia establishment would have to assume. The number of filters of the mechanical form necessary for your work, together with their housings, would unquestionable be of imposing proportions. While I look favorably upon mechanical filtration for small towns, where the plant with its attendant steam plant and its

experimental field in question. One additional thought: As I understand the situation, the entire plant is to be turned over to the city at the end of a stated period. The life of an English filter plant should be indefinite like that of a reservoir or other similar structure, and its routine management should always keep it in perfect condition.

As to what the life of a mechanical plant may be, there are no facts whereon to base an opinion, but it is self-evident that the valves, the tubs holding the sand, and the machinery used for washing, must be renewed after no great lapse of years. In other words, the plant must be replaced after an interval more or less long.

Yours respectfully,

(Signed) WILLIAM P. MASON.

(Copy.)

OFFICE OF RUDOLPH HERRING,

NEW YORK, Sept. 14, 1897.

THOMAS M. THOMPSON, ESQ.,
Director Department of Pubcic Works,
Philadelphia, Pa.

DEAR SIR:

Your favor of August 25th was duly received, asking my views and opinions on the subject of filtering the Philadelphia water supply.

The pressure of other business has delayed my responding to the questions contained in your letter, and now I find that further lack of time prevents my answering them as fully as I had at first intended. I trust, however, that the reply may be sufficient for your present purpose.

The questions and my answers to them are as follows:

First · What would be, in your opinion, the best system of filtration for the City of Philadelphia to adopt?

The Delaware and Schuylkill rivers are the two available sources of supply which are now being considered. The waters of both rivers are at times very turbid and at other times clear. Both rivers receive the sewage of the towns situated on their course, the Schuylkill water being the more highly polluted. The Schuylkill river also contains at times much coal dust washed down from the coal regions.

With these conditions and in order to keep the necessary filter areas and the expense of filter cleaning as small as possible, it is economical to have either a sufficiency of subsiding basins, in which the turbid water can clarify itself before it is passed through the filters, or to have sufficient reservoir capacity for the filtered water, so as to allow pumping from the river to be suspended while the water runs excessively turbid.

The former method is usually the better, as it is also the more common one. Filtered water should be consumed as quickly as possible after leaving the filters; if it is to be subsequently exposed in open reservoirs to the sun's rays and to the dust of the air, some of the benefits which are expected to be derived from filtration will be lost unless the reservoirs are covered.

To answer your question regarding the best system of filtration for Philadelphia, with some degree of definiteness under the conditions just stated, I am obliged to distinguish only between two systems of filtration, namely the rapid and slow systems. These terms are used because the former contemplates purifying water at a rate of 300 to 400 cubic feet, and the latter only from 5 to 10 cubic feet per day, per square feet of filtered surface.

The former system represented by a variety of designs and embodied under the general term of "mechanical filter," requires that a solution of alum or a simular coagulant be added to the water, in order to rapidly form a film which retains the fine suspended matter and the bacteria. The system of slow filtration, represented by large areas of sand beds and a variety of details, does not necessarily require such material to be added, and depends mainly upon the oxygen contained in the water, to oxidize the least stable particles of the organic matter, and upon a natural film of organic matter, which soon coats the top layers of the filters, to retain the bacteria. After cleaning the filters in both systems, it is necessary to allow the water to run to waste until the respective films have formed again. As mechanical filters are of necessity washed more frequently, perhaps once a day, while the slow filters can run from one to two months, the loss of water for cleaning the rapid filters is greater.

Regarding the efficiency to remove bacteria, we have still but few data. The results of the Louisville experiments with mechanical filters, which will soon be published, I believe, are expected to throw considerable light on this subject. Meantime, we are safe in stating that when in operation their practical efficiency in this respect will not exceed the efficiency of slow filters.

Therefore, with some uncertainties still on the side of the mechanical filters, with a bacterial efficiency no greater, and perhaps less than the slow filters, and with the larger quantity of water that must be used for washing, and must run to waste until the effective film has formed again, I consider that the slow filtration method requiring large beds of sand, the cost being the same, is the preferable one, with our present knowledge, for the waters under consideration. Preliminary settling basins are, no doubt, essential for the Schuylkill River water, and possibly also for the Delaware River water, which question may only be answered by experiment, and certainly only after thorough examination.

Second: Have you information as to the kind and character of filtration adopted in Europe, and of what success?

I have visited many of the European filter plants, and am familiar with their character and success. Briefly stated, they are all of the type which I term "slow filtration," and no city of any size in Europe has as yet used mechanical filters, although the city of Moscow is at present considering the expediency of adopting them.

The success of the European filtration works, such as those of London, Liverpool, Hamburg, Altona, Berlin, Amsterdam, Rotterdam, Zurich and others, some of which purify badly polluted water, is undoubted, although it is admitted that not only the construction, but mainly the operation, must be conducted with considerable intelligence and care in order to obtain the desired results.

Third: What system of filtration is the best to remove bacteria and disease germs?

Awaiting the publication of the results of experiments made on this important subject in Louisville, it is practicable now to state only that we have ample evidence from Europe that slow filtration removes almost all bacteria, including disease germs, from the water, and cannot say that mechanical filters, where they have been operated and examined with equal care, have done any better, and generally not as well.

Fourth: What system of filtration is the most permanent, and in the end proves most satisfactory?

So far as durability is concerned, the slow filters are the more permanent, because they are built of masonry, while the mechanical filters are built of iron or wood, and require more machinery than the others in operation.

As to which system will in the end prove most satisfactory, depends upon the character of the water, the degree of its pollu-

tion, and the care and intelligence with which the filters are designed and operated. Assuming the latter condition to be the same in both cases, then I can say that the more highly polluted the water, the greater is the satisfaction to be derived from slow filtration, because the reduced number of cleanings lessens the chances of careless operation, and the opportunities for the passage and escape of disease germs. Water that is not polluted with sewage can, in my opinion, be filtered with equal satisfaction by mechanical filters.

Fifth: Have you any data as to the cost of mechanical and sand filters?

I am in possession of such data as they have been available to the profession. Reducing the cost to a convenient unit, namely for filtering 1,000,000 gallons of water, these data show that, exclusive of land, and under favorable conditions, a large plant of open sand filters, operated at the rate of 2,000,000 gals. per acre, per day, costs from $20,000 to $30,000 per 1,000,000 gallons. The cost of operating a large plant, exclusive of interest, etc., ranges from $4.00 to $6.00 per 1,000,000 gallons.

The cost of mechanical filters for a plant comparable with the above should be between $15,000 to $25,000 per 1,000,000 gallons, and the cost of operating, exclusive of interest, etc., also from $4.00 to $6.00 per 1,000,000 gallons.

The cost, however, depends so much on local conditions that no general statement can be made which has more than general interest. Under average conditions we may say that the cost of slow and rapid filters is nearly the same. There are special conditions, however, where one or the other system may be cheaper. Only an investigation of each particular case will give the basis for a comparative estimate of cost.

Very truly yours,

(Signed) RUDOLPH HERRING.